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BRICs – their impact on global environment

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Abstract: The BRIC countries have been in a process of fast economic growth for more than a decade and the growth seems to continue. Economic growth is often linked to the use of fossil fuels and the release of greenhouse gases. The accumulation in the atmosphere of greenhouse gases contribute to global warming and the risk for climate change. The objective is to study the impact on global environment of the use of fossil fuels in the BRICs. The impact is limited to carbon dioxide. The historical development of economic growth and carbon dioxide outlet in the individual BRIC countries is reviewed and possible scenarios for the future are discussed to find out the impact of a business as usual scenario on the global environment in the future. The development in the BRICs is compared with the World and the developed regions of the US and EU. The overall conclusion is that the BRICs will be responsible for a major part of the carbon dioxide outlet in the future. The BRICs may, without any further climate policies and programs, be a threat to global environment. There is a significant potential to reduce the carbon dioxide outlet but it is not likely to happen unless the BRICs face a dramatic climate change. However, the position of the individual BRICs is different. Brazil seems to be in the best position to limit the carbon dioxide outlet in the future while China and India compete about the worst position.

Key words: BRICs, scenario, carbon dioxide, emissions, environment, climate change

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Content:

Acronyms:

AIS	Accelerated Improvement Scenario
BRIC	Brazil, Russia, India and China
C	Carbon
CI	Carbon Intensity (CO2/E)
CIS	Continued Improvement Scenario
CO2	Carbon Dioxide
CO2eq	Carbon Dioxide equivalent
E	Energy Use
EPA	Environmental Protection Agency
EI	Energy Intensity (E/GDP)
ERI	Energy Research Institute (in China)
EU	European Union
GDP	Gross Domestic Product
GDP per capita	GDP/POP
GHGs	Green House Gases
Gt	Giga ton
IEA	International Energy Agency
IPCC	International Panel on Climate Change
LNG	Liquefied Natural Gas
LUB	Lund University Libraries
kt	Kilo ton
MJ	Mega Joule
Mt	Million ton
PNMC	National Plan on Climate Policy (in Brazil)
POP	Population
ppm	Parts per million
UN	United Nations
UNFCCC	United Nations Framework for Climate Change
US	United States

Section 1: Introduction

The concern of global environment started to grow during the second part of the last century and was manifested by a United Nations Conference on Environment and Development in Rio de Janeiro in 1992. The aim was to establish international guidelines for the protection of environment and a sustainable development (UN, 2014a). The acceleration of the industrial revolution during the past 200 years had resulted in a growing use of fossil fuels. These fuels released by combustion a lot of harmful emissions to the atmosphere on the one hand and on the other hand they were not renewable. The emissions of sulphur and nitrogen gases and particles were already during the 19th century a local problem but often neglected. In England where the first industrial revolution took off these problems had been obvious for more than a century before the authorities really took action in the 1950s (Logan, 1953).

There was a further potential environmental problem which was not visible like the smog and could not be smelled like the sulphur. That was the outlet of greenhouse gases (GHGs) by the production and use of energy. The increase of GHGs in the atmosphere will increase the temperature on earth. The risk of global warming and climate change is obvious (IPCC, 2014).This is not a local problem as the atmosphere is shared by the whole population and all countries in the world. The effect on climate is difficult to predict and might be irreversible. At the time for the Rio conference the effects of increasing GHGs was still debated among scientists but brought to the agenda in Rio where over 170 countries participated and more than 100 of them had sent their highest ranked government officials.

The outcome of the conference in Rio de Janeiro was a declaration where the countries agreed to work towards international agreements “which respect the interests of all and protect the integrity of the global environment and development systems, recognizing the integral and interdependent nature of the Earth, our home” (UN, 2014a). The declaration was based on 27 principles (UN, 2014a). The work in this spirit continued and in 1997 the Kyoto Protocol to the United Nations Framework Convention on Climate Change was agreed. This is an international treaty with binding obligations to reduce emissions of GHGs in industrialised countries with a few exceptions (UNFCC, 2014). US did not agree as China was not willing to commit to any firm reductions. But even without US and China this was a first step to start reduce the impact of human induced GHGs on climate change. The Protocol was adopted in 1997 and entered into force in 2005. Many of the developed countries have agreed to legally binding reductions of their emission of GHGs. There are two commitment periods 2008-2012 respectively 2013-2020. The European Union (EU) even established a trading system for the emissions of GHGs to meet the goals set (EU, 2005).

In the annual climate negotiations taking place after the ratification of the Kyoto Protocol the industrialised countries with binding commitments are trying to convince not only US and other countries in the developed world to do the same but also discuss how to get the fast growing developing countries to introduce binding commitments. This is a hot question as the developing countries often ague that they should have the same right as the developed world to raise their standard of living and that it would be difficult if not impossible with binding commitments on the emission of GHGs. The developing world is further arguing that the industrialised countries have used the atmosphere for free as a sink for GHGs and they do not now want to take the burden of lower their economic growth (Jiborn and Kander, 2013). Though the main focus of this essay is not to discuss the burden sharing it will be inevitable to touch on that issue later on in the discussion of the results.

A group of developing countries often showing up in the discussion of binding commitments are the BRICs. The term BRIC was coined in a paper by Goldman Sachs (O'Neill, 2001). BRIC is the abbreviation of Brazil, Russia, India and China. The BRIC countries cover more than 25 % of the land on earth and have about 40 % of the global population (Wikipedia, 2014). They have shown a remarkable development during the past decades and Goldman Sachs predicted in 2001 a fast economic growth for the BRICs. A fast economic growth is often related to increased energy consumption based on fossil fuels. In turn this results in increased outlet of GHGs to the atmosphere. The accumulation of GHGs in the atmosphere is a significant driver of global warming (EPA, 2014).

In the annual climate change negotiations under the UN lead the BRIC countries often stick together when the developed countries invite them to commit themselves to firm reductions of their GHGs outlet in order to protect the global environment. In these negotiations the BRICs normally argue that the developed countries have contributed to the accumulation of carbon dioxide far more than BRIC and that they have a fair right to aim for the same living standard as the developed countries. The developed world has the main responsibility for threat to the global environment according to them.

In a working paper from 2009 the conclusion is that the BRICs will not commit themselves to binding agreements, neither singly or collectively, as long as climate change is not dramatic (Tian and Whally, 2010). The result in the paper shows that trade sanctions towards the BRIC countries are not likely to convince them to binding agreements. Financial transfer might do but they have to be large (Tian and Whally, 2010). Technology transfer can be one form of financial support from the industrial countries to the BRICs. The use of modern technology may help the BRICs to reduce both energy and carbon intensity.¨

The argument that the developing countries want to raise their living standard and thereby reduce poverty is accepted by most countries in the developed world and is high on the agenda in the Millennium Development Goals (UN, 2014b). The developed world has for sure contributed to the accumulation of GHGs in the atmosphere for a long time. But the fast growing countries in the developed world are catching up and are now responsible for a substantial part. The argument that the developed countries are the main responsible is getting weaker and weaker as the energy consumption in the fast growing part of the developing world is increasing fast and the outlet of GHGs in the corresponding way. However, the fast economic growth in the developing world has been made possible by the technology from the industrialised countries (Jiborn and Kander, 2013). This indicate the complexity of the debate about who has to take the responsibility of reducing the outlet of GHGs. Even with modern technology and lower and lower energy and carbon intensity in the BRICs the absolute level of GHGs is likely to increase in the short run as the intensity measures are relative. For the global environment it is the outlet of GHGs in absolute terms that matters, not the energy and carbon intensity (IPCC, 2014). The question to be discussed in this essay is if the impact from the BRICs can be considered a threat to global environment.

The introduction will be followed by a definition of the research question and the limitations in section 2. Then the method will be described in section 3 and the data sources in section 4. Section 5 will describe the current energy systems in the BRIC countries. The development of the annual economic growth rate will be reviewed in section 6. The outlet of carbon dioxide during the past two decades and GDP in 2005$ will be presented in section 7 together with a few key indicators. Based on the historical development the past trend will be extrapolated in a business as usual scenario in section 8. In section 9 a number of scientific articles for the individual BRICs will be reviewed and compared with the extrapolation of the trend in the previous section. The Kaya identity will be introduced in section 10 as a tool to analyse and discuss the individual BRICs drivers of emissions and potential solutions to reduce their outlet of carbon dioxide. In section 11 the future of the BRICs in terms of carbon dioxide outlet will be discussed. Finally, in section 12 the research questions are addressed and the conclusions formed.

Section 2: Research questions and limitations

The more overall and general question, if BRICs can be considered as a threat to the global environment is now broken down into two specific research questions:

- How can the absolute outlet of GHGs from the BRIC countries be expected to develop compared to the world, EU and US?
- Does any of the BRICs have a more favourable position when it comes to reducing the outlet of GHGs?

Several gases are classified as GHGs and the primary GHGs are shown in Figure 2.1. The major ones are carbon dioxide and methane both related to the use of energy, but also other activities. In this essay the focus will be on the energy sector. Carbon dioxide is released by combustion of fossil fuels and methane in limited amounts by production of coal, oil and gas. The increasing use of fossil fuels since the first industrial revolution has increased the concentration of carbon dioxide in the atmosphere and is a major reason to the threat to the global environment (EPA, 2014).

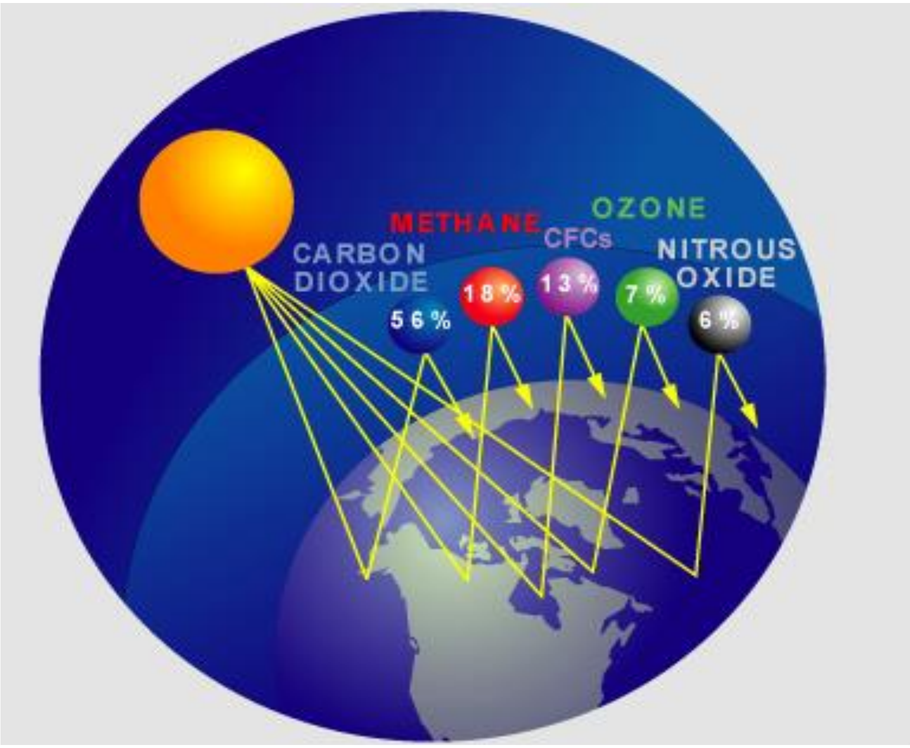

Figure 2.1 Greenhouse Gases. Source: Life of Earth (http://lifeofearth.org)

In the following the analysis of the impact of GHGs on climate change will be limited to the impact of carbon dioxide from the energy sector. Carbon dioxide is always formed by combustion of fossil fuels like coal, oil and natural gas and contributes to the concentration of carbon dioxide in the atmosphere. The different fuels generate more or less carbon dioxide in relation to their energy content. In the Table 2.1 the different emission factors are shown.

Table 2.1 CO2 emission factors in gram CO2/MJ. Source: Levander, 1991

Coal	92
Oil	74
Natural gas	56

The analysis of the outlet of carbon dioxide from a country can be undertaken from different aspects. The simplest way to this is to use the production method. This means that all sources of carbon dioxide in a country are added together. This method does not take into account the trade flows between countries. The weakness of the production method is that it does not give any information about the outlet of carbon dioxide related to the actual consumption in a country. A rich country can outsource production of goods, and thereby parts of their carbon dioxide outlet, to developing countries and then import the goods for consumption. The consumption method has the advantage that international trade is considered but is much more complex compared to the production method as it requires a lot more information. A major drawback with the consumption method is that countries do not have to take responsibility for the carbon dioxide outlet from the export industry. The method has no incentives for the export industry to improve energy and carbon efficiency. To eliminate this a third method, the NEGA method is proposed by Kander (Jiborn and Kander, 2013).

In this essay the production method will be used as the main focus to discuss the impact on global environment and not to allocate the carbon dioxide outlet to a specific country. Only the territorial outlet is considered. This approach can be seen as a limitation but will keep the analysis on a basic level. In the next chapter the method used will be described.

Section 3: Method

The first step will be to describe the current energy mix and the primary energy consumption in each country. The latest information about the energy mix found in the data sources is from 2011. Then the historical development of the economic growth rate, the carbon dioxide outlet and income per capita since 1992 are analysed for the BRICs and as a comparison for the World, US and EU. The starting point is 1992 for the time series. It could have been better to have used 1990 as the first year as 1990 has been used as the reference in the Kyoto Protocol, but unfortunately there is no complete information for Russia available in the World Bank Open Database before 1992. The annual economic growth rate has been used to describe the economic development for the period 1992-2012. This period has been divided in two sub-periods 1992-2001 and 2002-2012 to be able to verify the statement in the earlier referred Goldman Sachs paper from 2001 that states that the BRICs are fast growing and will continue to grow fast (O'Neill, 2001). These periods have also been used in the analysis of the trend in carbon dioxide outlet together with the total period. The latest official information in the World Bank Open Database about carbon dioxide outlet is from 2010.

The trends in economic growth rate and the outlet of carbon for the BRIC countries will be calculated and compared with the corresponding trends in US, EU and World. The trend for World excluding BRIC will also be calculated to illustrate the relation between BRICs and the rest of the world. The trends will then be an input for the discussion of the future development of carbon dioxide emissions. Further, relation between carbon dioxide outlet and the GDP in 2005$, carbon intensity of GDP, will be calculated for the BRICs and compared with World, US and EU and discussed.

In the second step the future will be analysed. How will the current trend in outlet of carbon dioxide develop? The past trends will be used to develop two future scenarios for each of the BRICs. The first scenario assumes that the trend in carbon dioxide for the period 1992-2010 will continue until 2020, 2040 and 2060 with the real outcome from 2010 as the starting point. In an alternative scenario the trend from 2002-2010 will also be used to create a comparison. These scenarios can be considered as business as usual with a normal development of technology without any additional or new climate policies. Then a number of scenarios found in the scientific literature will be reviewed, both business as usual scenarios and scenarios based on specific policies and programs to reduce the carbon dioxide outlet. The scenarios will then be compared and discussed.

The third step will use the Kaya identity to illustrate the differences in some key parameters between the BRICs and discuss the potential for reduction of carbon dioxide outlet in the future. The carbon and energy intensity in the BRICs will be related to World, US and EU to indicate the potential to reduce carbon dioxide outlet. The discussion will be foremost qualitative and relate to the specific characteristic of the energy system in each country. This will show the individual position of each BRIC to deal with the reduction of carbon dioxide. These three steps form the basis for the conclusion and the answers to the research questions in the final section of this essay.

Section 4: Data Sources

In the description of the energy systems in the BRIC countries the latest information from US Energy Information Administration (EIA) has been used. This is a public data source which builds the information on a large number of different sources like academic journals, business journals, government information, public market analysis, news agencies and newspapers. As statistical information always is lagging behind the information provided regards 2011. EIA states itself as an independent source.

The World Bank Open Database has been used as source for the historical data about carbon dioxide outlet, economic growth, population and GDP. A few indicators for the future have also been taken from this database.

The LUB database has been the main source for searching for scientific literature. In addition the Google Scholar Database has been used in some cases. Internet has been used as a source, in particular the information from United Nations has been found there.

Section 5: Energy systems in the BRIC countries

5.1 Introduction

The present energy systems in the BRIC countries are in this section described in general and in overall terms to form a basis for the analysis and discussion in this paper. Focus will be on primary energy consumption in each country.

The following definition of primary energy is used: "Energy in the form that it is first accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy" (EIA, 2014c). The difference between primary, secondary and tertiary energy can be illustrated by the following example. If coal as the primary energy source is converted to gas, gas will be the secondary energy source. Gas can be used directly for e. g. heating purposes but another possibility is to convert gas to electricity, and in the latter case electricity will be the tertiary energy source. Secondary and tertiary electricity are converted to primary energy by using the heat rate of the actual plant. In the case of nuclear electricity generation the same principle is used. Electricity generation by wind and solar is converted to primary energy in the same way but as the plants normally do not have any plant heat rate a typical heat rate from a fossil fuel plant is used (EIA, 2014c).

The use of fossil energy is decisive for the level of carbon dioxide formed and thereby the impact of the environment. The share of fossil energy in the primary energy consumption is thus a main characteristic of the energy system. Energy intensity and carbon intensity are other characteristic parameters but they are relative measures. The global environmental impact of carbon dioxide is however related to the absolute level of carbon dioxide outlet. Therefore the intensity measures can only be used as complementary information to the absolute levels. Further, import and export of fossil energy are additional characteristics of the energy system in a country and disclose information about interdependency between countries.

5.2 Brazil

In Brazil the total primary energy consumption in 2011 is shown in Figure 5.1:

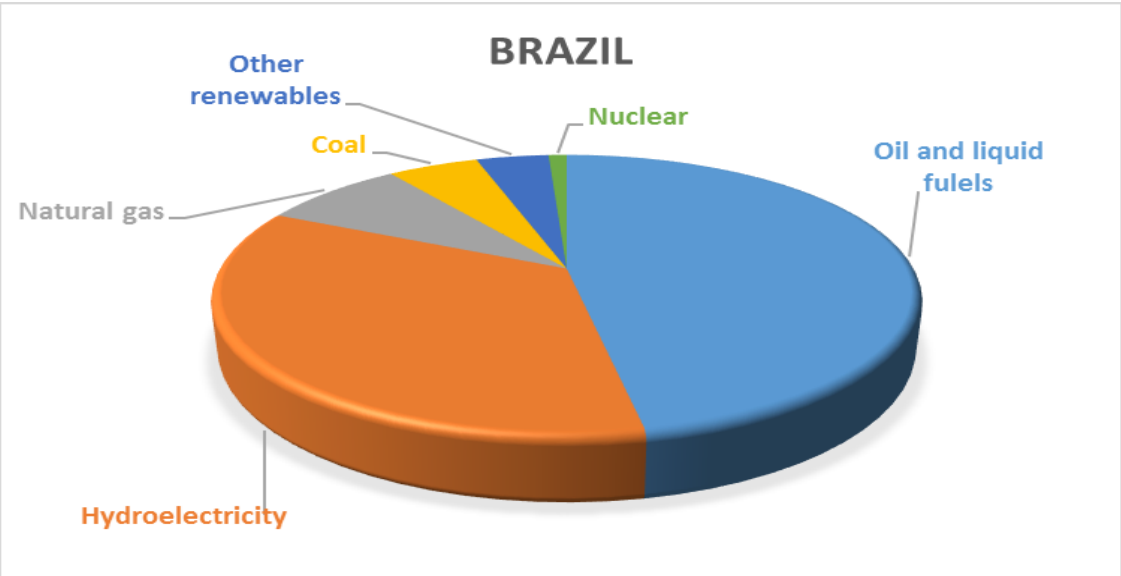

Figure 5.1 Energy consumption in Brazil 2011. Source: EIA, 2013a

Oil and other liquid fuels is the largest segment with about 47 % of the primary energy consumption. About 80 % in this segment is coming from crude and condensates. Other liquid fuels contain ethanol from sugar cane and cannot be considered as a fossil fuel generating any carbon dioxide. The second largest segment is hydroelectricity with about 35 % of the total energy consumption. Nuclear and renewables other than ethanol are relatively small and they represent 1 % respectively 4 % Assuming that other liquid fuels are dominated by ethanol the total energy consumption in Brazil, regarded as carbon dioxide free, is close to 50 % (EIA, 2013a).

Among the fossil fuels used in Brazil oil is the dominant. Coal and gas are today relatively small. The dependency of oil in the past was one reason for Brazil to encourage the production of ethanol quite early. Brazil is second to Venezuela when it comes to oil production in South America. After a few years of surplus in the oil balance Brazil is now back in the situation that the consumption of oil is higher than the production (EIA, 2013a). Brazil has significant oil reserves but most of them are offshore and in very deep water. This makes it both technical difficult and costly to exploit them. In addition the reserves consist of heavy grades to great extent. The largest oil discoveries in the world has during the last years been related to offshore pre-salt basins in Brazil. The Brazilian government has allocated significant investments for exploration and production activities. An indicator that Brazil is committed to use the domestic oil to meet domestic consumption demand.
Brazil is the third largest energy consumer in Americas after US and Canada. In world Brazil was ranked in 2010 as eighth largest energy consumer (EIA, 2013a).

5.3 Russia

The total primary energy consumption in Russia in 2011 is shown in Figure 5.2:

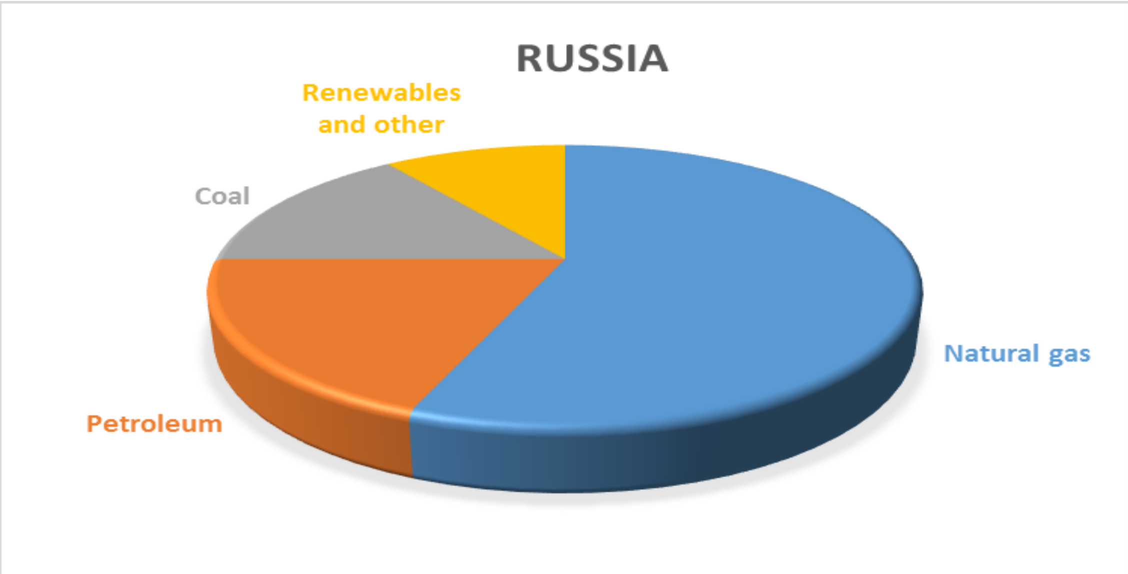

Figure 5.2 Energy consumption in Russia 2011. Source: EIA, 2014a

In Russia natural gas is the major source in the primary energy consumption and is responsible for more than 50 % of the consumption. The contribution of oil and coal are significant, both between 15 and 20 %, resulting in about 90 % of the primary energy consumption supplied by fossil fuels. Renewable and other energy resources are making up the rest and consist of nuclear, hydroelectricity, geothermal and biomass. The latter one only contributes to about 1 %. Nuclear and hydroelectricity are the major parts in this sector (EIA, 2014a). They are not contributing to the carbon dioxide outlet but there may be a potential to change the energy mix by increasing the proportion of renewable and other resources. Russia has a relatively ambitious program for expand nuclear energy (Enerdata, 2013).

Natural gas and oil are supplying around 75 % of the domestic primary energy demand in Russia. In addition Russia exports significant volumes of natural gas and oil through pipelines and ports to other countries. Both pipelines and ports require a fair amount of investment to make the export possible. Considerable investments are already taken and new pipelines and ports are planned to further boost the export of natural gas and oil. A public owned company has the monopoly over the pipeline network in Russia. Pipelines are less flexible when it comes to the receiving party and during the last years seaborne exports have been more favoured. Pipelines outside Russia are sometimes difficult to control when political conflicts emerge.

Pipelines for natural gas are recently built and Russia has further plans to expand the infrastructure both to Europe and Asia. Before a decision to build a pipeline a long term contract has to be in place with a buyer in the other end of the pipe. Such a contract has often a duration of 15-25 years. The consequence is that when a pipeline is built it is likely to be used for a substantial time.

Russia is the second largest producer in the world of dry natural gas after US and third in rank when it comes to liquid fuels behind US and Saudi Arabia. Further, Russia holds the largest proven reserves of natural gas and as well significant reserves in oil (EIA, 2014a).

5.4 India

In India the total primary energy consumption in 2011 is shown in Figure 5.3:

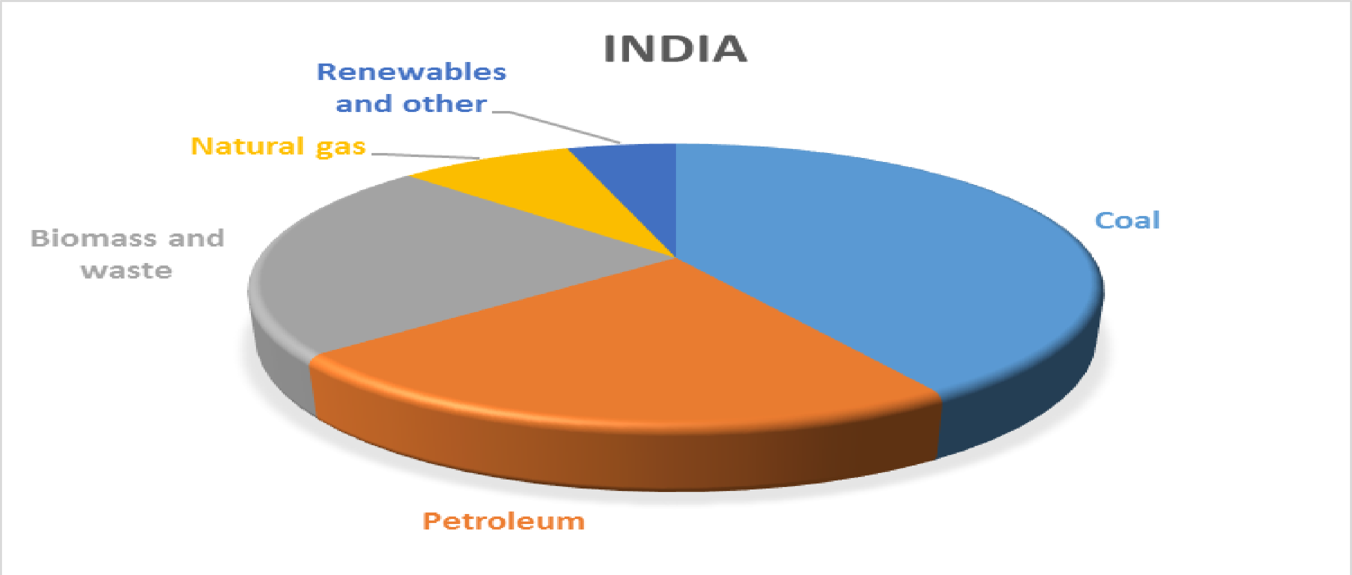

Figure 5.3 Energy consumption in India 2011. Source: EIA, 2013b

In India coal is the major energy resource covering more than 40 % of the energy consumption. The sectors solid biomass including waste and oil are both responsible for around 23 %. Natural gas accounts for about 8 % and nuclear together with other renewables for the remaining 5 %. Fossil fuels in total are responsible for more than 70 % of the primary energy consumption (EIA, 2013b).

India imports oil, natural gas and coal and is the fourth largest consumer of energy in the world after US, China and Russia. The dependency of oil import has been both strong and increasing during the past decade. Only about a third of the oil consumption of today can be supplied by domestic oil. The import of oil comes mainly from the Middle East. India was self-sufficient of natural gas until 2004 but after that India relies more and more on liquefied natural gas (LNG) imports. India is investing in regasification plants to meet the growing demand. India is also planning to import dry natural gas through pipelines. In 2012 India signed a contract with Turkmenistan. The coal reserves in India are the fifth largest in the world but the coal sector is centralised and very inefficient and has not been able to meet the domestic demand. India's coal imports have grown annually by more than 10 % since 2001 (EIA, 2013b).

5.5 China

The total primary energy consumption in China in 2011 is shown in Figure 5.4:

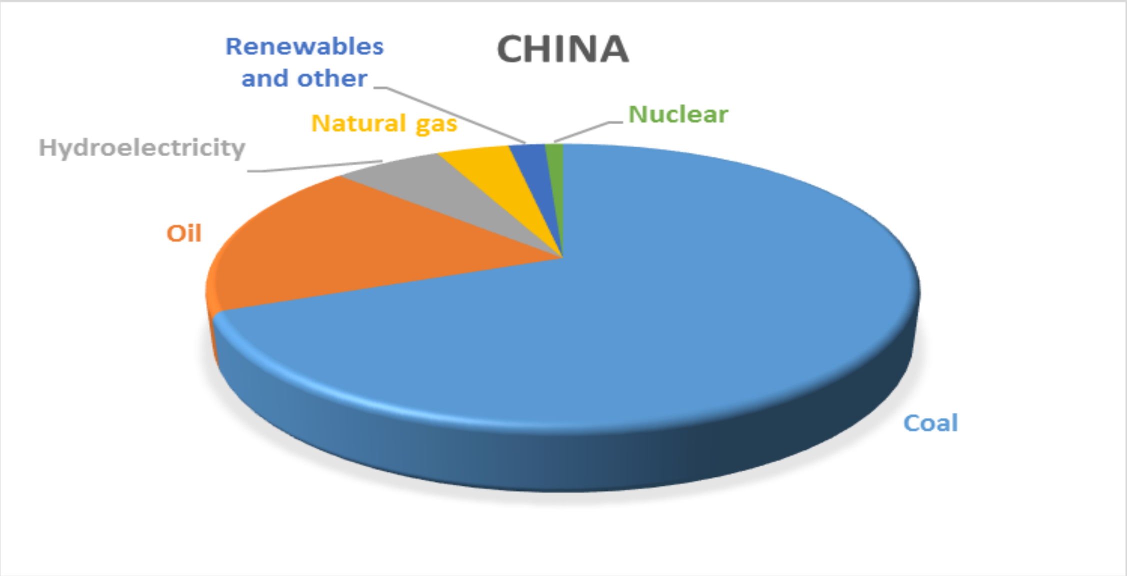

Figure 5.4 Energy consumption in China 2011. Source: EIA, 2014b

In China coal is the dominant energy resource in the primary consumption with almost 70 %. Oil and natural gas is responsible for 18 % respectively 4 %. Over 90 % of the energy consumption is based on fossil fuels. Hydroelectric power is covering about 6 % and nuclear power less than 1 %. The rest is made up by other renewable energy resources.
The demand for oil has increased much faster than the domestic production of oil since the early 1990s. The largest oil fields in China are mature and have to use various enhancement techniques to keep up production. This requires new investments short term but long term the production is likely to decline. China therefore has to spend significant amount of investment on exploration and new production. In addition, the Chinese national oil companies have started to make acquisitions of international oil and natural gas assets to secure future oil and gas supplies. By these long term investments China also gain technical expertise which can be used in the domestic field (EIA, 2014b).

The demand for natural gas in China is rising fast and heavy investments in the development of new production and greater import opportunities will probably lead to a substantial growth of the natural gas sector. China also invests in new pipelines for import from bordering countries (EIA, 2014b). Russia and China have recently signed a 30 year agreement of natural gas deliveries from Russia to China (Bloomberg, 2014). China is expected to be the largest energy consumer in the world 2014.

5.6 Summary and remarks

In summary, the dependence of the fossil fuels coal, oil and natural gas varies across the BRIC countries. A comparison between the countries in terms of fossil and non-fossil fuels and dominant fuel is estimated in Table 5.1:

Table 5.1 Fossil vs non-fossil fuels in the BRICs. Source: EIA

Country	Fossil	Non-fossil	Dominant
Brazil	50 %	50 %	Oil (38 %)
Russia	90 %	10 %	Natural gas (56 %)
India	70 %	30 %	Coal (41 %)
China	90 %	10 %	Coal (69 %)

Brazil is the less dependent country among the BRIC countries and Russia the most dependent country when it comes fossil fuels. Russia and China are both heavily dependent on fossil fuels but in the case of China coal is the dominant energy resource while in Russia it is natural gas. In terms of carbon generation, coal is much worse than natural gas. Over 50 % more carbon dioxide is released by combustion of coal compared to natural gas, see Table 2.1. The potential in China to reduce carbon dioxide outlet through a change in the energy mix is therefore high but might be difficult as coal is a domestic fuel and the import of natural gas and oil may be expensive for the Chinese as the global reserves are limited and the discussion about “Peak Oil”, maximal extraction, has been on the table for some years already.

The high economic growth rate in China but also in India and Brazil is likely to make these countries dependent on energy imports for the foreseeable future and therefore a reduction in the absolute use of fossil fuels seems difficult even if they manage to change the energy mix. Brazil seems to be in the best position as the non-fossil fuels are already providing about 50 % of the primary energy resources and that infrastructure for producing and using ethanol is in place. In the case of Russia economic growth is dependent of energy exports to a high degree as around 50 % of GDP is related to the income from energy export. The dominant energy resource in Russia is natural gas which is the best fossil fuel from a low carbon generation perspective. The potential for changing the energy mix is therefore low compared to China.

Section 6: Historical economic growth in the BRICs

6.1 Introduction

The BRIC countries were in the beginning of the 2000s in a process of fast economic growth. (O’Neill, 2001) In this section the economic development in terms of annual GDP growth will first be reviewed in order to verify the prediction of Goldman Sachs stating that the BRIC countries will grow faster than the developed world (ONeill, 2001). The available data in the World Bank Open Database for all BRICs start in 1992 and the latest are from 2012 when it comes to annual economic growth rate. A main reason for this is that the World Bank does not present any GDP data for Russia before the breakdown of the former Soviet Union. In addition the new economic order in India was introduced in the early 1990s (EIA, 2013b). Two time periods, 1992-2001 and 2002-2012 are selected to verify the prediction.

6.2 Annual economic growth rate

The annual economic growth rate is first commented on for the individual BRIC countries and then the mean values for the chosen periods are calculated and summarised. For a comparison the same procedure is used for the World, US and EU. At the end the result is summarised and concluded with some remarks.

6.2.1 Brazil

The annual growth rate of GDP in Brazil is shown in Appendix 1 Diagram 6.1 and it is obvious that the economic growth rate has varied during the period from a few years with slightly negative GDP to several years above 3 percent which in the developed world is quite good. The mean value of the annual growth rates for the period 1992-2001 is about 2.5 percent and for the period 2002-2012 is about 3.5 percent. This indicates that the economic growth rate has accelerated during the first decade of the 2000s compared to the 1990s. The growth rate recovered quick after the recession in 2008/2009 but after that it has declined.

6.2.2 Russia

The annual growth rate of GDP in Russia is shown in Appendix 1 Diagram 6.2 and shows that the negative growth rate during most the years in the 1990s shifted to a clearly positive economic growth rate during the 2000s with an exception for the recession 2008/2009. The mean value of the annual economic growth rate during the period 1992-2001 is -2,5 percent but shifts to 4.9 percent during the period 2002-2012. The first decade in the 2000s shows a stable and high GDP growth until the recession hits the economy in 2009. The recovery in 2010 of the growth rate is then followed by a decline just as in Brazil though not that strong.

6.2.3 India

The annual growth rate of GDP in India is shown in Appendix 1 Diagram 6.3 and shows that India during the whole period 1992-2012 has had a growth rate above 3 percent. India reached the highest growth rate in 2010 with over 10 percent. The mean value of the annual growth rate is high for the period 1992-2001 and about 6 % but during the period 2002-2012 even higher, 7.3 percent. This indicates an upward trend in economic growth, though the annual rates 2011-2012 seems to drop.

6.2.4 China

The annual growth rate of GDP is shown for China in Appendix 1 Diagram 6.4. During the period 1992-2012 China shows a high and stable economic growth rate, varying between 7 and 14 percent. The mean of the annual growth rate is for the period 1992-2001 around 10.4 percent and for the second period 2002-2012 around 10.3 percent. The trend seems sideways on a remarkable high level.

6.2.5 Summary and remarks

The mean value of the annual GDP growth rate in the BRIC countries since the Goldman Sachs article in 2001 is shown in Table 6.1 1992-2001 for the periods 1992-2001 and 2002-2012.

Table 6.1 Annual GDP growth in the BRICs. Source: World Bank Open Database

Country	1992-2001	2002-2012
Brazil	2.5 %	3.5 %
Russia	-2.5 %	4.9 %
India	6.0 %	7.3 %
China	10.4 %	10.3 %

The BRIC countries show high but also varying GDP growth rates. The most remarkable is the growth rate in China though it is slightly lower for the latter period. The mean value of the annual growth rate has stayed on the level of 10 % for about two decades. The trend has been sideways. In India, second behind China, the GDP growth rate has also been impressive and in an upward trend during the last two decades. Brazil also shows an upward trend but the absolute level of GDP is lower. Russia shifts from a negative annual GDP growth rate to a clearly positive one between the periods and the trend is upwards.

6.2.6 In comparison with World, US and EU

The BRIC countries will now be compared to two major players in the developed world and the mean value for the World. The annual economic growth in US, EU and World is shown in Appendix 1 Diagram 6.5 to 6.7.

The annual economic growth rate calculated in the corresponding way as for the BRICs is shown in Table 6.2.

Table 6.2 Annual GDP growth in World, US and EU. Source: World Bank Open Database

Region	1992-2001	2002-2012
World	2.8 %	3.2 %
US	3.6 %	1.8 %
EU	2.3 %	1.2 %

The first observation is that the US and EU show a reverse trend when it comes to growth in GDP compared to the BRICs. The second one is that the level of economic growth is substantially lower for US and EU compared to the World during the last period.

6.3 Conclusion

The anticipated rapid economic growth in the BRIC countries has been verified. Even if Brazil is just above the average growth rate of the World the rest of the BRIC countries are clearly above. The BRIC group has, without doubt been growing fast during the past decade. The next question to be elaborated on is, how has this rapid economic growth influenced the outlet of carbon dioxide in relation to GDP in these countries?

Section 7: Historical carbon dioxide outlet relative GDP in the BRICs

7.1 Introduction

The outlet of carbon dioxide from the BRIC countries and their GDPs in constant US$ of 2005 will be reviewed and commented on. The time period chosen for the discussion of the development is 1992-2010 for all countries as the latest information in the database on carbon dioxide outlet is from 2010. All indicators will be compared with the corresponding indicators for US, EU and the World for the same period.

7.2 Brazil

In Appendix 1 Diagram 7.1 the CO2 outlet in absolute terms is shown for the period 1992-2010 and in Diagram 7.2 the development of GDP. The outlet of CO2 has almost doubled from about 220 Mt in 1992 to about 420 Mt in 2010. The trend is clearly upwards though a decline from one year to next can be seen when the economic growth slows down. The growth in CO2 outlet 1992-2001 seems to be higher compared to the period 2002-2010.
The development of carbon dioxide outlet in relation to GDP in 2005$ for the years 1992, 2001 and 2010 is shown in Table 7.1 for Brazil.

Table 7.1 Carbon intensity of GDP for Brazil in ton CO2 per 1000 US 2005$. Source: World Bank Open Database

	1992	2001	2010
Brazil	3.65	0.43	0.38

7.3 Russia

The absolute level of the CO2 outlet in Russia during the period 1992-2010 and GDP is shown in Appendix 1 Diagram 7.3 respectively Diagram 7.4. The CO2 outlet fell significantly from 1992 to 1998 and then stayed fairly constant until 2003 when a slight upwards trend can be seen until 2009 when it drops and then return to a level slightly above 2008. The CO2 outlet in 2010 is 1740 Mt and is clearly below the level of 2140 Mt in 1992. The development of carbon dioxide outlet in relation to GDP in 2005$ for the years 1992, 2001and 2010 is shown in Table 7.2 for Russia.

Table 7.2 Carbon intensity of GDP for Russia in ton CO2 per 1000 US 2005$. Source: World Bank Open Database

	1992	2001	2010
Russia	3.13	2.01	1.91

7.4 India

The CO2 outlet during the period 1992-2010 is shown in Appendix 1 Diagram 7.5 in absolute terms for India and in Diagram 7.6 the GDP development for the same period. The trend is clearly upwards during the whole period. There are no signs of any drop in the CO2 outlet in years with a lower economic growth rate. Even during the recession in 2008/2009 the outlet of CO2 increases. The level of CO2 outlet in 1992 is around 785 Mt which has increased to more than the double in 2010 or about 2000 Mt. The development of carbon dioxide outlet in relation to GDP in 2005$ for the years 1992, 2001 and 2010 is shown in Table 7.3 for India.

Table 7.3 Carbon intensity of GDP for India in ton CO2 per 1000 US 2005$. Source: World Bank Open Database

	1992	2001	2010
India	2.10	1.91	1.61

7.5 China

The carbon dioxide outlet in China for the period 1992-2010 is shown in Appendix 1 Diagram 7.7 in absolute terms and indicate a slow growth until the Asian financial crisis in 1997, then a sideways movement until 2002 and after that a really fast growth. In Appendix 1 Diagram 7.8 the GDP development is shown and as in India there is no sign of the recession in the global economy in 2008. The outlet of carbon dioxide in 2010 is over 8000 Mt and more than 2.5 times the level of 1992. The development of carbon dioxide outlet in relation to GDP in 2005$ for the years 1992, 2001 and 2010 is shown in Table 7.4 for China.

Table 7.4 Carbon intensity of GDP for China in ton CO2 per 1000 US 2005$. Source: World Bank Open Database

	1992	2001	2010
China	4.11	2.27	2.16

7.6 Comparison with World, US and EU

In Appendix 1 Diagram 7.9 to 7.13 corresponding graphs are shown for World, US and EU as comparison.

7.7 Summary and remarks

The outlet of carbon dioxide in Mt per year is summarised for the BRIC countries in Table 7.5

Table 7.5 Outlet of CO2 in Mt per year for the BRICs. Source: World Bank Open Database

Country/Year	1992	2001	2002	2010
Brazil	221	337	332	420
Russia	2140	1558	1558	1740
India	789	1204	1227	2009
China	2696	3488	3694	8287
BRIC total	5846	6587	6811	12456

The BRIC countries show an increasing trend in the outlet of carbon dioxide for the period 2002-2010. This goes also for the period 1992-2001 for all countries except Russia. The likely explanation to the decrease in carbon dioxide outlet in Russia 1992-2001 is that the breakdown of the Soviet Union caused the closure of inefficient industries. This assumption is supported by the negative economic growth rate during this period. In Brazil and India the carbon dioxide outlet in the period 1992-2001 increased by roughly 50 % and in China by about 30 %.

The comparison of the outlet of carbon dioxide in the period 2002-2010 shows that China more than doubled its outlet while the trend in economic growth rate stayed on a high and rather stable level. India increased its outlet by roughly 60 % with the second best annual economic growth rate. Russia with the third best annual growth rate only increased its outlet by a bit more than 10 % while Brazil with the lowest annual growth rate increased its outlet by about 30 %.

The comparison of the outlet of carbon dioxide in the BRIC countries on the one hand and US, EU and World on the other in the corresponding way is shown in Table 7.6.

Table 7.6 Outlet of CO_2 in Mt per year. Source: World Bank Open Database

Region/Year	1992	2001	2002	2010
BRIC total	5846	6587	6811	12456
US	4920	5600	5650	5430
EU	4050	4000	3970	3710
World	22300	25400	25600	33600
World-BRIC	16454	18813	18789	21144

The increase of the carbon dioxide outlet in the World, the BRICs excluded from 1992 to 2010 is 4690 Mt compared to 6610 Mt for the BRICs during the same period. The carbon intensity of GDP 2005$ for the BRICs are summarised in Table 7.7 together with the corresponding values for US EU and World.

Table 7.7 Carbon intensity of GDP for BRICs, US, EU and World in ton CO_2 per 1000 US 2005$. Source: World Bank Open Database

Region/Year	1992	2001	2010
Brazil	3.65	0.43	0.38
Russia	3.13	2.01	1.91
India	2.10	1.91	1.61
China	4.11	2.27	2.16
US	0.58	0.49	0.40
EU	0.39	0.32	0.26
World	0.71	0.62	0.65

The comparison in Table 7.7 shows that the BRICs have decreased their carbon intensity of their GDP over the period and in particular Brazil. Brazil has reached a level in 2010 below the world average and even slightly below US. The transformation of the energy system in Brazil to a substantial level of ethanol use is likely one explanation. (EIA, 2013a) The rest of the BRICs are in 2010 still on a level more than double the world average and compared to EU the level is rather 6-8 times higher.

7.8 Conclusion

The carbon intensity of GDP is significantly higher in the BRICs, except Brazil, compared to the developed world but also higher than world average. Though the carbon intensity of GDP has declined since 1992 the absolute outlet of carbon dioxide has continued to increase. The challenge to further decrease the carbon intensity of GDP for the BRICs remains. There seems to be a huge potential but are the BRICs in the position to catch the opportunity? The BRIC countries have more than doubled the outlet of carbon dioxide during the period 1992-2010 while US has increased the outlet by about 10 % and EU decreased its outlet by nearly 10 %. The World has increased the outlet of carbon dioxide with approximately 50 % but with the BRICs excluded only by less than 30 %. This indicates a substantial impact of the BRICs. Other countries than the BRICs and the US also contribute to the increase of outlet of carbon dioxide but the BRICs are major contributors. Comparing the BRIC countries with US and EU in the latter period 2002-2010 is even more striking. BRICs have increased the outlet of carbon dioxide with more than 80 % while both the US and EU has slightly decreased their outlet. The divergence is obvious. The increase of the carbon dioxide in the BRIC countries during the period 2002-2012 is greater than the average yearly outlet in US during the same period. The question is now, will the divergence continue? In the next sections the future development will be discussed.

Section 8: A scenario for the future outlet of carbon dioxide from the BRICs

8.1 Introduction

The future development of economic growth and outlet of carbon dioxide is not easy to predict. However, in the short and medium perspective it will be difficult to significantly change the outlet of carbon dioxide in the BRIC countries as their present energy systems are given and major investments in production of fossil fuels are in the pipe.

In this section a simple extrapolation of the current trend of carbon dioxide outlet will first be presented. The assumption is that the development of the outlet of carbon dioxide in the BRIC countries will follow the trend in the outlet of carbon dioxide during the period 1992-2010. The trend can be calculated in different ways. The simplest way to calculate the trend is by using the first and last observation in their respective time series and number of observations. In this case the rest of the observations does not matter. But the calculation of the trend can be done in a second way (Hudson, 2011:124). The calculation of a trend using all observations can be expected to give a better result using a regression approach (Hudson, 2011:126).
In the following the trend will be calculated for the BRIC countries in these two ways. First using only the first and last observation during the period 1992-2010 and second using all observations during the period. The outcome will summarised and commented on and then compared with the corresponding calculations for US and EU and the World.

8.2 Extrapolation of trend for the BRICs

A linear trend for the outlet of carbon dioxide has been calculated using two methods. The first method (Method 1) is using only the first and the last observations in the time series 1992-2010 while the second one uses all observations (Method 2). The result in terms of increase or decrease of carbon dioxide outlet in Mt per year is shown in Table 8.1.

Table 8.1 Annual change of CO2 outlet in Mt in the BRICs 1992-2010. Source: World Bank Open Database and own calculations

Country	Method 1	Method 2
Brazil	+9.0	+9.5
Russia	-10.4	-19.0
India	+63.6	+58.3
China	+298.5	+266.2
BRIC total	+360.7	+323.0

This shows that China and to some extent India dominate BRICs outlet of carbon dioxide to the atmosphere. The outlet from India increases every year by around 60 Mt with this assumption. This is more than the Swedish annual outlet which has been stable over the past years on a level of around 50 Mt (Jiborn and Kander, 2013). In the case of China the outlet would increase by nearly 300 Mt annually or five times India's outlet of carbon dioxide. The annual increase of the outlet of carbon dioxide in Brazil seems quite modest in absolute terms. In the case of Russia the trend is negative for the whole period 1992-2010, but for the last decade it shows a slight upwards trend. A possible explanation is that the inefficient industry was closed down after the breakdown of the Soviet Union in the early 1990s. Another reason could be a shift in favour of natural gas.

8.3 Comparison with US, EU and World

The trend in the outlet of carbon dioxide in US, EU and the World using the same methods as above is shown below in comparison with BRIC total.

Table 8.2 Annual change of CO2 outlet in Mt for BRICs total, US, EU and World Source: World Bank Open Database and own calculations

Region	Method 1	Method 2
BRIC total	+360.7	+323.0
US	+34.7	+26.9
EU	-9.5	-18.1
World	+651.3	+593.0

First US and EU show different direction in the trend. US increases the outlet of carbon during the period 1992-2010. But the annual increase is less than 10 % of the increase in the BRIC countries. EU on the other hand shows a decline in the outlet of carbon dioxide during the period. The decline is in comparison with the fast growth in BRICs quite modest. EU would need more than 30 years to compensate for the annual increase of the Chinese outlet of carbon dioxide with this linear assumption.

The trend for the World indicate that the BRICs will be responsible for more 50 % of the annual growth rate in carbon dioxide outlet in the world. The contribution from the US is in this perspective small and the negative trend in EU does not impact the total very much. A significant reduction of carbon dioxide outlet in the BRICs, in particular China, will have a substantial impact on the global situation. However, the development of this scenario is based on a simple extrapolation. In the next section more complex scenarios will be reviewed.

Section 9: Emission scenarios in the scientific literature

9.1 Introduction

In the review of the scientific literature numerous emission scenarios have been found, though no one specifically dealing with the BRICs as a group. Therefore the most recent and relevant scenarios found in the database for each country have been reviewed to create a view on the BRICs as a group. The data studied above show that China is responsible for the major part of the carbon dioxide outlet from the BRICs and is therefore accordingly in the focus in most the articles. India is second in this respect. In this section the focus will be on all the BRICs but inevitable the parts of China and India have to be more extensive compared to the other countries as the scientific reports have reviewed China and India more closely. At the end all BRICs will be summarised and compared with the simple extrapolation in section 8.

9.2 Brazil

In Brazil the main source of carbon dioxide outlet is not the use of fossil fuels but comes from the deforestation which has taken place during the first decade of the 21st century. In the study of future outlet of carbon dioxide it is therefore of importance to keep this in mind. In a recent adopted law, National Plan on Climate Policy (PNMC), the Brazilian government has the goal to reduce the scale in deforestation until 2017 with 70 %. At the same time the use of fossil fuels is expected to increase in absolute numbers but also as share of the total outlet of carbon dioxide. The ambition is to reduce the emission intensity by 2020 by 36-39 % in the overall economy (Chen et al, 2013).

A business as usual scenario, based on the assumptions above and that no further policies are introduced to reduce carbon dioxide outlet, is developed for the period 2020 to 2040 Chen et al, 2013). In addition to this scenario, three more scenarios are developed with assumptions about how effectively the PNMC target is achieved varying from 50 % to 100 % (Chen et al, 2013). For the analysis of the scenarios a series of mixed complementary problems (MCP) is formulated (Mathiesen, 1985). To solve the problems a special modelling language was used (Rutherford, 1999).

The result in a business as usual scenario indicates that the annual total carbon dioxide outlet in Brazil could increase by about 50 % from the level in 2010 (1742 Mt) to 2040 (2610 Mt). The outlet from energy consumption and industrial processes would increase almost three-fold in this period from 483 Mt to 1351 Mt. This implies that the share of carbon dioxide outlet from energy consumption and industrial processes will increase from about 25 to more than 50 % (Chen et al, 2013).

The additional scenarios of different levels of implementation of PNMC show that the target for reduction in carbon dioxide outlet set in PNMC can be reached with very low or even no reduction at all from energy consumption and industrial processes if the 70 % reduction rate of deforestation is maintained until 2040. However, if the reduction rate in deforestation is only half the burden on economy will be much larger and cutting the emissions from energy consumption and industrial processes has to start already in 2015 to fulfil the national goal. If Brazil fails to implement the PNMC totally a carbon tax is an option to reduce the outlet of carbon dioxide in Brazil (Chen et al, 2013).

9.3 Russia

The future GHG emissions in Russia has been projected in several studies in the past years by both national and international scholars. About 70 different scenarios have been reviewed in a recent study (Bashmakov and Myshak, 2014). This study will be the basis for the discussion in this section unless otherwise is stated. The scenarios are developed by help of models of different complexities, different assumptions and forecast range. The scenarios have been grouped in five different categories. In the discussion below two of these categories are chosen for a further review. The first category is the “baseline zone” which is a sort of business as usual scenario. The basic assumption is that economic growth and the development of energy efficiency very much follow past patterns. The second category to be elaborated on is the “low carbon Russia” scenario. This category of scenarios will illustrate the potential reduction of GHGs if Russia strengthens the policies on GHG control. The scenarios cover a time period from 2020 to 2060 and the emissions are given in a carbon dioxide equivalent (CO2eq). This means that other GHGs than carbon dioxide are included. The level of the emissions in 2010 is 1820 Mt carbon dioxide equivalent and these are taken as the baseline for the comparison of later years. The results are given as ranges in Mt of carbon dioxide equivalent for the two categories of scenarios in Table 9.1.

Table 9.1 Scenarios for carbon dioxide outlet in Russia in Mt CO2eq. Source: Bashmakov and Myshak, 2014

Year	Baseline zone	Low carbon Russia
2010	1820	1820
2020	2270-2420	1820-1855
2030	2720-3020	1820-1890
2040	3170-3620	1820-1925
2050	3620-4220	1820-1960
2060	4070-4820	1820-1995

In a business as usual case the emissions in 2010 seems to increase roughly 2.5 times while they in the low carbon case only increases slightly or not at all. If the composition of GHGs are constant over the period this conclusion also goes for the outlet of carbon dioxide. The low carbon scenario indicates a fair chance for Russia to keep the outlet of carbon dioxide rather constant over the next decades.

In order to get an estimation of the absolute amount of carbon dioxide in the GHGs the data for 1990 can be used where 2715 Mt of GHGs contains 2287 Mt carbon dioxide. This means that about 85 % of GHGs are carbon dioxide already in 1990.

A further comparison can be made with 11 scenarios made for the electricity sector in Russia (Steenhof and Hill, 2006). In this study the carbon dioxide outlet is projected for 2010 and 2020. The projections for 2010 varies between 576 and 709 Mt and for 2020 between 541 and 792 Mt. With the assumption that the electricity sector contributes to 30 % of the national outlet of carbon dioxide in Mt is shown in Table 9.2.

Table 9.2 Scenarios for carbon dioxide outlet in Mt in Russia. Source: Steenhof and Hill, 2006 and own calculations

Year	2010	2020
Russia all sectors	1920-2360	1820-2640

Even if the projection for 2010 in these scenarios seems to be a bit high the projection for 2020 seems to be in line with the later forecasts.

9.4 India

An Indian version of the Global Change Assessment Model (GCAM-IIM) has been used to develop the future development of the energy system and carbon emissions in India (Shukla and Chaturvedi, 2012). Two of the scenarios will be reviewed here. First, a business as usual scenario without any targets on the electricity sector and the carbon price. Second, another scenario with targets on the electricity sector. The reason for this is that emissions from the electricity sector today make up close to 40 % of the total carbon emissions and this share is likely to increase in the future when the Indians will catch-up with the developed world in terms of electricity per capita (Remme et al, 2011). The time frame for the scenarios is 2005-2095.

The result indicate that the emissions of carbon increases from an annual level of 357 Mt C in 2005 to more than 3600 Mt C in 2095 in the case of business as usual without any targets. In case of targets on the electricity sector the level in 2095 will be reduced to about 3360 Mt C per year. The decrease of the cumulative emissions between 2005 and 2050 is calculated to around 1400 Mt C and the corresponding decrease between 2050 and 2095 to about 7200 Mt C. The effect of the targets is about 4 % for the first sub-period and 6 % for the second one (Shukla and Chaturvedi, 2012).

The outlet of carbon increases by 10 times during the whole period and the estimation of the annual outlet in 2050 is about 2000 Mt C. In order to make the comparison with other sources Mt C is recalculated to Mt CO2 in Table 9.3 for the business as usual scenario without targets.

Table 9.3 Carbon dioxide outlet in India in Mt. Source: Shukla and Chaturvedi, 2012 and own calculations

Year	2005	2050	2095
India	1310	7330	12320

The future emissions in India will grow but the question is how fast. Several attempts has been made to develop a business as usual scenario for India. The modelling efforts show a wide range of result (Fujiwara, 2010). In this paper a comparison of five different studies is discussed. Different models and methods are used and the assumptions varies. The results from the independent studies indicate that around 2030 the absolute levels of the annual outlet of carbon dioxide could be in the range of 4000 to 7300 Mt (Fujiwara, 2010). Based on the past trends the concluding estimate is that the annual carbon dioxide outlet by 2030 is likely to be below 4000 Mt. This corresponds to an annual growth of the carbon emissions in the range of 3 to 4 % (Fujiwara, 2010). This indicates more than a doubling of the carbon dioxide outlet until 2030.

The conclusion for India is that in a business as usual case the carbon dioxide outlet will grow substantially over the next decades. The ambition is to cut the emission intensity by 20-25 % until 2020 and that seems not impossible (Stern and Jotzo, 2010).

9.5 China

In an integrated assessment model called WITCH the future development of energy use and the carbon dioxide outlet has been studied (Carraro and Massetti, 2011). The aim of the study is to study how different carbon tax regimes may impact the outlet of carbon dioxide in China. The base for this study is a business as usual scenario where no action is taken to reduce the carbon dioxide outlet. In addition five other scenarios have been created to study the impact of carbon taxation in terms of dollar per ton on carbon emissions, carbon intensity of energy and GDP. Parameters of interest, addressed in the study, are power generation technologies and the macroeconomic cost in the five additional scenarios. The forecasting period is from 2010 to 2100.

The study in itself imply a major concern about the fast growing carbon dioxide outlet in China and that the long term impact on environment. The business as usual scenario delivers projections for China and the World for the period 2010-2100 for a number of parameters. In the tables below the predictions for carbon dioxide outlet, both in absolute numbers and per capita, and the carbon intensity of energy are summarised for China and the World in Table 9.4, Table 9.5 and Table 9.6 respectively.

Table 9.4 Scenario for CO2 emissions in Gt in China. Source: Carraro and Masetti, 2011

Region/Year	2010	2030	2050	2100
China	6.8	12.6	17.9	20.9
World	29.0	42.7	59.2	80.2

Table 9.5 Scenario for CO2 emissions per capita in ton in China. Source: Carraro and Masetti, 2011

Region/Year	2010	2030	2050	2100
China	5.0	8.6	12.6	17.4
World	4.2	5.1	6.4	8.8

Table 9.6 Scenario for carbon intensity of energy in ton of CO2 per Mtoe in China. Source: Carraro and Masetti, 2011

Region/Year	2010	2030	2050	2100
China	3.48	3.44	3.50	3.71
World	2.73	2.84	3.02	3.35

The projected absolute outlet of carbon dioxide in Table 9.4 for 2010 is lower compared to the actual outcome according to World Bank Open Database, see Table 7.5. Further, the predicted share of the outlet carbon in China compared to the World is higher in the World Bank Open Database, 24.7 % compared to 23.4 %. This indicates that the gap between China and the World has continued to grow during the end of the first decade of the 2100th century. A comparison between China and the rest of the World is shown in Table 9.7.

Table 9.7 Comparison of outcome and forecast for 2010 of carbon dioxide outlet in China. Source: World Bank Open Database and Carraro and Masetti, 2011

Region	Outcome 2010	Forecast 2010
China	8.3	6.8
Rest of World	25.3	22.2
China/Rest of World	32.8 %	30.6 %

It seems likely that the business as usual scenario has underestimated the strong growth in China though it was created only a few years before 2010.
A corresponding comparison of carbon dioxide outlet per capita gives the following result in Table 9.8.

Table 9.8 Comparison of outcome and forecast for 2010 of carbon dioxide outlet per capita in China. Source: World Bank Open Database and Carraro and Masetti, 2011

Region	Outcome 2010	Forecast 2010
China	6.2	5.0
World	4.9	4.2
China/World	1.27	1.19

The real outcome in 2010 shows that the carbon dioxide per capita in China is 27 % higher than in the World, while the scenario, created only a few years before 2010, projects 19 % higher per capita carbon dioxide outlet.

The projection of carbon intensity of energy is compared by real outcome according to data from the World Bank Open Database in Table 9.9.

Table 9.9 Comparison of outcome and forecast for 2010 of carbon intensity of energy in China. Source: World Bank Open Database and Carraro and Masetti, 2011

Region	Outcome 2010	Scenario 2010
China	3.29	3.48
World	2.69	2.73
China/World	1.22	1.27

The real outcome shows lower carbon intensity of energy for 2010 than the scenario and the gap to the World is lower. China's carbon intensity was only 22 % higher than World average in 2010 compared to 27 % higher in the scenario.

The final conclusion of the business as usual scenario commented on above is that without any specific measures, in terms of climate policies, the carbon dioxide outlet in China will grow significantly during the next decades. A continued fast economic growth without any significant change in the carbon content of energy will not reduce the carbon dioxide outlet. The return to levels of energy efficiency improvements from the 1980s and 1990s will not be enough to stabilize the carbon dioxide outlet. Carbon taxation is a climate policy that could be used to reduce the carbon dioxide outlet but that will be to the price of lower GDP growth (Carraro and Masetti, 2011).

Another approach to study potential future pathways for carbon dioxide emission is to create scenarios based on cumulative emission budgets (Anderson et al, 2008). This is based on the fact that GHGs as carbon dioxide stay in the atmosphere more than 100 years and has been used by the Tyndall Centre (Bows et al, 2006). In a paper from 2010 this approach has been applied on China to develop four scenarios for 2000 to 2100 (Wang and Watson, 2010). The global cumulative emission budget required to stabilise concentration of carbon dioxide in the atmosphere at 450 ppm is 490 Gt of carbon (IPCC, 2007). This might be too optimistic today (Wang and Watson, 2010).

The allocation of the cumulative emission budget to China has been along two principles. The first one is equal emissions per capita among countries and the second one equal emissions intensity of GDP. Two existing pathways to 2020, developed by the Chinese Energy Research Institute (ERI) and the International Energy Agency (IEA), were used as starting point for the scenarios (Wang and Watson, 2010). Each of the scenarios was created along both principles and the Chinese cumulative emission budget was allocated with peaking year 2020 and 2030 according to Table 9.10.

Table 9.10 Emission scenarios for China using cumulative budget of carbon. Source: Wang and Watson, 2010

Scenario	S1: ERI	S2: ERI	S3: IEA	S4: IEA
Cumulative budget Gt C	70	111	90	111
Peaking year	2020	2030	2020	2030

This approach illustrates the dilemma China faces. Higher and later peaks are likely to result in steeper subsequent emission reductions which probably will be challenging. An early peak in China would require substantial changes in economic structure and energy system (Wang and Watson, 2010). The peaks in the four scenarios are described in Table 9.11.

Table 9.11 Emission scenarios for China showing the peak year and the annual emission. Source: Wang and Watson, 2010 and own calculations

Scenario	S1: ERI	S2: ERI	S3: IEA	S4: IEA
Peak Mt C	1700	1850	2450	2550
Peak Mt CO2	6230	6780	8980	9350
Peak year	2020	2030	2020	2030

The scenarios start to converge after their peaks but in 2050 they still show a wide range of annual emissions between approximately 450 and 1250 Mt C, respectively 1650 and 4580 Mt CO2. The annual levels are in 2100 further reduced to approximately 200 to 300 Mt C, respectively to 730 and 1100 Mt CO2 (Wang and Watson, 2010). This is on a significantly lower level than in the business as usual scenario showed above (Carraro and Masetti, 2011). This indicates that emissions can be reduced by improving energy efficiency and shifting to low carbon technologies in the long run, at least on a theoretical level. But this is not likely to happen without the introduction of ambitious policies to reduce the emission of carbon dioxide (Wang and Watson, 2010).

A further method used to develop trajectories for future energy demand and emissions is the bottom-up approach. The models based on the bottom-up approach analyses the pattern of energy consumption in different sectors related to energy using equipment in each sector. In the next two scenarios for China developed by the End-Use Model from Lawrence Berkeley National Laboratory will be discussed (Zhou et al, 2013). First a reference scenario, called CIS, is developed. The CIS assumes that China follows the current pathway to lower the energy intensity and that policies and programs already in place or on the table are implemented in a successful way. This scenario can be considered in line with current trends, market based and a sort of business as usual. The second scenario is called AIS and assumes more aggressive policies and programs to reach current best practise earlier than in the CIS. This will result in the implementation of key alternative energy technologies.

The sectors considered in the model are residential, commercial, industry, transport and power. The primary energy use increases in both scenarios until around 2030 and then flattens out. The emission of carbon dioxide reach a peak approximately about the same time though AIS a few years earlier than in the CIS. Then the emission of carbon dioxide decreases until 2050. A bit more in the case of AIS. The numbers for the annual outlet are shown in Table 9.12 and compared with the actual outcome in 2010 according to World Bank Open Database in Mt.

Table 9.12 Scenarios for carbon dioxide outlet in China in Mt Source: Zhou et al, 2013 and World Bank Open Database

Year	2010	2030	2050
CIS	8287	11931	11192
AIS	8287	9680	7352

The result shows that the industrial and commercial sectors have the greatest potential to reduce the outlet of carbon dioxide in the AIS compared to CIS (Zhou et al, 2013). This illustrates the importance of being able to form policies and programs not only in general terms but also on sector level. The overall reduction in carbon intensity in the CIS until 2020 is about 43 % compared to the level of 2005 and correspondingly for the AIS is 49 %. For 2050 the reduction potential is 82 % respectively 88 % (Zhou et al, 2013).

The last set of scenarios to be discussed in this section is based on a multi-regional hybrid model called ReMIND-R (Steckel et al, 2011). This model combines an economic growth model with a bottom-up model of the energy system and a simple climate model. The model is used to develop a baseline scenario without any specific climate mitigation efforts more than that the business as usual improvement of technology is assumed to continue and lower energy efficiency. In addition to the baseline scenario three more scenarios are developed to describe the future development with the restriction that the concentration of carbon dioxide in the atmosphere will be stabilised on 500, 450 respectively 400 ppm. The time frame for the scenarios are 2005 to 2050. The results from the scenarios are given for China and the World (Steckel et al, 2011).

In the baseline scenario the global annual carbon dioxide outlet in the World is projected to double from 32 Gt in 2005 to 65 Gt in 2050. This corresponds to an annual growth rate of about 1.6 %. For China the increase will be more than threefold during the same period (Steckel et al, 2011). As no absolute numbers for China is given in the paper “threefold” can be transformed to an annual growth rate of approximately 3.2 % or more. The average annual growth rate of carbon dioxide emissions in China is double compared to the World and indicate the urgency for China to take action to reduce the outlet of carbon dioxide.
In the scenario where carbon dioxide concentration in the atmosphere is stabilised on the level of 450 ppm the global accumulated emissions in the World has to be reduced by about 48 % compared to the baseline scenario. China’s share of the global accumulated emissions in the 450 ppm scenario is about 16 % and the reduction below the baseline 43 % (Steckel et al, 2011).

9.6 Summary and remarks

The review of the scientific literature shows the difficulty to develop comparable scenarios for the future outlet of carbon dioxide for the BRICs. A wide range of different models have been used with different approaches. There are top-down approaches, bottom-up approaches and a combination of both. Assumptions about GDP growth, development and diffusion of new or improved technology and its impact on energy efficiency, the change in energy mix and its impact on carbon intensity and different types of policies and programs to reduce the outlet of carbon dioxide varies from study to study. But based on these assumptions trajectories for the outlet of carbon can be calculated over time from a starting point. In some studies only carbon is studied, in others carbon dioxide and a third approach is to study GHGs as a carbon dioxide equivalent including also other GHGs than carbon dioxide. This makes it difficult to compare different studies without any recalculations. A further way of attacking the development of scenarios is to start from a given carbon dioxide budget and adjust the development of other parameters to comply with long term carbon budget. All these types of approaches have been discussed on an overall level to form a basis for the summary of the review of the individual BRIC countries.

In summary the estimations of the carbon dioxide outlet for 2020, 2040 and 2060 compared to the latest outcome from 2010 (World Bank Open Database) in Mt carbon dioxide can be seen in Table 9.13. This shows what can be considered as business as usual scenarios. By the conversion from Mt C to Mt carbon dioxide the factor 3.67 has been used (CDIAC, 2014). Linear interpolation has been used if the outcome from a scenario is not available for the chosen years. Further when the estimation is given as an interval the middle value has been chosen.

Table 9.13 Carbon dioxide outlet in Mt per year Source: World Bank Open Database and own calculations

	2010	2020	2040	2060
Brazil	420	770	1351	1640
Russia	1740	2355	3395	4450
India	2009	2010	4680	8440
China	8287	9700	15300	18500
BRIC total	12456	14835	24726	33030
World	33600	35900	51000	63400

9.7 Conclusion

The growth trend in the outlet of carbon dioxide from the BRICs based on the individual trend in each country during the period 1992-2010 indicates an annual growth rate of 320-360 Mt. See Table 8.1. This is lower than the increase in average annual outlet of carbon dioxide in the BRICs between 2020 and 2040 which can be calculated to 495 Mt. The corresponding annual increase in the period 2040-2060 is 415 Mt which is also higher than the extrapolation of the trend suggests.

In Table 9.13 the number for the real outcome of the carbon dioxide outlet in 2010 is not comparable with the estimates for 2020, 2040 and 2060 as most of the scenarios are developed before the numbers for 2010 were known. The fact that the annual growth in the carbon dioxide outlet for the period 2010-2020 is only 238 Mt indicates that the starting point in these scenarios was too low. With the assumption that the increase of the annual growth is the same for 2010-2020 as for 2020-2040 and applying this to the World Bank Data from 2010 the result in Table 9.14 occurs.

Table 9.14 Scenario for carbon dioxide outlet and real outcome for 2010 in BRICs and World. Source: World Bank Open Database and own estimates

	2010	2020	2040	2060
BRIC total	12456	17046	27306	35606
World	33600	41150	56250	64650

The BRICs total share of the carbon dioxide outlet in 2010 is about 37 % and is estimated to about 55 % in 2060 in a business as usual scenario. The outlet of carbon dioxide from the BRICs seems to increase substantially in a business as usual case and even more than a simple linear extrapolation might forecast. The outlet from the BRICs in relation to the world is also increasing and as discussed above the likelihood that the BRICs will commit themselves to binding reductions in carbon dioxide outlet seems low, at least as long as their standard of living is lower than the developed world and unless they do not face any dramatic effects of climate change (Tian and Whally, 2010).

The scenarios where action is taken to reduce the carbon dioxide outlet, through climate policies and programs, show that there is a significant potential to reduce carbon dioxide outlet. But there is normally a cost associated to such measures in terms of lower economic growth or direct costs for e g technology transfer. This leads to discussions about how to share the burden to reduce carbon dioxide outlet and remove the threat to global environment (Jiborn and Kander, 2013). This is a complex issue and even if BRICs are considered as a threat to the global environment there are other parties as well which have to support a solution.

But as the BRICs are in focus in this paper the next section will discuss which BRIC country is in the best position to reduce the carbon dioxide outlet.

Section 10: The best position among the BRICs

10.1 Introduction

In the previous section it is shown that the BRICs will increase the outlet of carbon dioxide substantially if business as usual continues. Further, the scenarios where climate policies and programs to reduce carbon dioxide are introduced also show a significant potential to reduce the outlet of carbon dioxide. In this section the BRICs will be reviewed with the objective to find out if any of them have a more favourable position compared to the others to reduce their carbon dioxide outlet and vice versa. The analysis will be performed by using the identity proposed by Kaya (Girod et al, 2009). In the next section the Kaya identity is presented.

10.2 The Kaya identity

The Kaya identity is a basic formula used to decompose carbon dioxide and can be expressed as follows has been proposed by the Japanese energy economist Yoichi Kaya. This identity has been used in reports from IPCC (Girod et al, 2009) and is shown below:

$$CO2=CO2/E*E/GDP*GDP/POP*POP$$

The different factors are:

CO2	carbon dioxide outlet
E	energy use
CO2/E	carbon intensity of energy (CI)
E/GDP	energy intensity (EI)
GDP/POP	income per capita (Y/P)
POP	population

The carbon dioxide outlet a given year is dependent on three factors except the population, carbon intensity, energy intensity and income per capita.

10.3 The Kaya identity applied on the BRICs

The parameters carbon intensity, energy intensity and income per capita are calculated for each year in the period 1992-2010 and for each country. The calculations are presented in Appendix 1 Diagram 10.1-10.4 where the development of these parameters related to 1992 is shown together with the population development also related to 1992. In the next sections these parameters are commented on for each of the countries. This illustrates how the parameters have changed over time and will give a first starting point for the discussion about which country having the best position.

As the BRICs wish to raise their standard of living the improvement in GDP per capita has to be balanced by lower carbon and energy intensity if population is constant. But the population in these countries, except Russia, tends to grow and reinforces the pressure on carbon and energy intensity.

10.3.1 Brazil

In general the outlet of carbon dioxide from the energy sector is very low in absolute terms compared to the rest of the BRICs, see Table 9.13. The historical development of carbon intensity in Diagram 10.1 in Appendix 1 shows a slight increase until early 2000s and then returns to the same level as in 1992. Energy intensity is fairly stable over the period and the movement is rather sideways. Income as GDP per capita in 2005$ has increased around 44 % during the period and population with 26 %. As neither of the factors in the Kaya identity has decreased the carbon dioxide outlet has increased as seen before mainly due to higher GDP per capita and a growing population.

The carbon intensity is closely related to the energy system and its mix and the reversal of the slight increase in the first half of the period is probably related to the introduction of ethanol as a fuel for transportation. The potential for further reduction of the carbon intensity may be limited as Brazil already has an energy mix with about 50 % non-fossil fuels. Energy intensity has changed very little and here the potential to increase energy efficiency may be significant.

10.3.2 Russia

In Russia the carbon dioxide outlet in absolute terms is higher than in Brazil but lower than in India and China, see Table 9.13. The carbon intensity has decreased slightly as well as the population over the period. Energy intensity did rise a bit after the fall of the Soviet Union but then it has shown clear downward trend from 1998 to 2007 and then a slight increase is seen. The reverse can be seen for the GDP per capita. Compared to 1992 the GDP in 2005$ is about 40 % higher in 2010. This is close to the case of Brazil. The decline in energy intensity, carbon intensity and population has balanced the GDP growth and the carbon dioxide outlet is lower in 2010 than in 1992.

10.3.3 India

In India the carbon dioxide outlet is higher than Brazil and Russia but lower than in China, see Table 9.13. The population has increased by about 33 % over the period and the GDP per capita in 2005$ has increased 2.5 times in 2010 compared to 1992. Carbon intensity has increased by about 21 % but energy intensity has decreased by about 37 % during the period. The outlet of carbon dioxide has increased mainly due to the increased GDP per capita and population growth.

10.3.4 China

China has the highest level of carbon dioxide outlet among the BRICs and account for more than 65 % of the aggregated output from the group, see Table 9.13. The remarkable economic growth is the most important driver for the carbon dioxide outlet during the period. The GDP in 2005$ is in 2010 more than five times higher than in 1992. This is more than double compared to India. The population growth has been modest in China over the period, only about 14 % compared to 33 % in India. The carbon intensity in China has increased slightly but be trend seems to be more sideway than upwards. The energy intensity is the only parameter in the Kaya identity balancing the other ones.

10.3.5 Summary and remarks

In the Appendix 1 the Diagram 10.1 to 10.4 show the development of the Kaya parameters in relation to their values in 1992. In the Table 10.1 and Table 10.2 the annual growth rates for the Kaya parameters are shown for the periods 1992-2001 respectively 2002-2010.

Table 10.1 Annual growth rates 1992-2001 of Kaya parameters. Source: World Bank Open Database and own calculations

	CO2/E	E/GDP	GDP/POP	POP
Brazil	1.47	0.25	1.19	1.36
Russia	-0.77	-1.01	-1.18	-0.19
India	1.26	-2.19	3.74	1.60
China	-0.45	-5.33	7.93	0.88

Table 10.2 Annual growth rates 2002-2010 of Kaya parameters. Source: World Bank Open Database and own calculations

	CO2/E	E/GDP	GDP/POP	POP
Brazil	-0.80	-0.11	2.60	0.94
Russia	-0.09	-2.80	4.50	-0.22
India	-0.86	-2.49	6.06	1.26
China	1.24	-1.46	9.12	0.49

The comparison between the two periods shows that in Brazil all parameters contribute to the increase in carbon dioxide outlet in the first period but in the second period the negative growth in carbon and energy intensity counteract the growth in population and in income per capita. The strongest driver for carbon dioxide outlet in Brazil in the second period is income per capita. For Russia it is only income per capita in the second period driving the increase in carbon dioxide outlet. In India and China the main drivers in both periods are income per capita and population, though in the second period the income per capita is stronger and the impact from population growth has declined compared to the first period. Improved energy intensity in India and China counteract the carbon dioxide outlet in both periods. In India a bit more in the second period and in China less in the second period. Carbon intensity gives in India an additional contribution to carbon dioxide outlet in the first period but turns to a reduction in the second period while in China it is the other way around.

10.4 Comparison to World, US and EU

10.4.1 Introduction

In this section the development in the BRIC countries will be compared with other regions. Therefore the development in World, US and EU will be analysed in the corresponding way as for the BRICs. In Appendix 1 Diagram 10.5-10.7 the development of the Kaya parameters are shown relative to their values in 1992. The result in the graphs will be commented on in the next sections.

10.4.2 World

In the World the increased outlet of carbon dioxide has been driven mainly by economic growth and population growth as they have increased by about 30 % respectively 26 %.

Carbon intensity in the World has increased slightly over the period, by less than 4 %. In comparison with the BRICs India has increased by about 21 %, China by 7 %, Brazil by slightly above 3 % while in Russia the carbon intensity has declined by about almost 8 %. Energy intensity has declined in all BRICs except Brazil where the energy intensity has increased by about 2 % compared to 1992. In the other BRICs the reduction in energy intensity is larger than in the World with a reduction of almost 12 % during the period. In China the reduction in energy intensity is just above 50 % while in India the reduction is about 37 % and in Russia 34 %.

10.4.3 US

In US the drivers for the increase in carbon outlet has been economic growth and growth in population. The decrease in carbon and energy intensity has balanced this development. The carbon intensity has only declined by less than 2 % during the period while energy intensity has decrease by almost 30 %.

10.4.4 EU

In EU the development show a similar pattern though the increase in population has grown less rapid or by 5 % compared to 20 % in the US. The economic growth over the period is comparable with US and is about 30 % and close to the World average. Carbon intensity and energy intensity has both declined in EU. Carbon intensity more in EU than in US, in EU by more than 14 % and less than 2 % in US. Energy intensity has been reduced by almost 30 % in the US while less in EU, about 23 %.

10.4.5 Summary and remarks

In Appendix 1 the Diagram 10.5 to 10.7 the development of the Kaya parameters are shown in relation to their values in 1992. In the Table 10.3 and Table 10.4 the annual growth rates for the Kaya parameters are shown for the periods 1992-2001 respectively 2002-2010.

Table 10.3 Annual growth rates 1992-2001 of Kaya parameters. Source: World Bank Open Database and own calculations

	CO2/E	E/GDP	GDP/POP	POP
World	0.58	0.03	1.35	1.27
US	0.05	-1.89	2.12	1.06
EU	-0.88	-1.42	2.01	0.18

Table 10.4 Annual growth rates 2002-2010 of Kaya parameters. Source: World Bank Open Database and own calculations

	CO2/E	E/GDP	GDP/POP	POP
World	-0.80	-0.11	1.34	1.07
US	-0.24	-1.69	0.70	0.81
EU	-0.72	-1.18	0.80	0.36

The growth in income per capita and population in EU is more than balanced by reduced carbon and energy intensity in both periods while in US this is true only for the second period. The World has managed to reduce both carbon and energy intensity during the second period but not enough to reduce the outlet of carbon dioxide.

10.4.6 Conclusion

The development of carbon and energy intensity in the BRICs varies over the period 1992-2010. In the discussion of the future development these parameters play an important role together with expected economic growth and population growth.

The BRICs wants to catch up in standard of living and therefore they aim for continued high economic growth. The population growth depends on demographic factors and is not likely to change fast, though population growth can be expected to slow down as the living standard is rising. The remaining question is how large is the potential to reduce intensity further. In the next section the relation between BRICs and the World on one hand and US respectively EU and the World on the other will be discussed.

10.5 Potential to reduce carbon intensity in the BRICs

In order to judge the potential for the BRICs to reduce their carbon and energy intensity the relation between carbon intensity respectively energy intensity and in the BRICs and World, US respectively EU. The calculated factor compares the carbon intensity in the individual BRIC countries with the intensity in World, US respectively EU at three different years in the past, 2000, 2005 and 2010 and is shown in Appendix 1 Diagram 10.8 to 10.10. The diagrams show that EU is the toughest benchmark for the BRICs and therefore the comparison with EU is used in the Table 10.5 to indicate the potential for reduction in carbon intensity. A factor greater than 1 indicates that the carbon intensity level in a BRIC country is higher than EU and vice versa.

Table 10.5 Carbon Intensity in the BRICs relative EU. Source: World Bank Open Database and own calculations

	2000	2005	2010
Brazil/EU	0.76	0.71	0.73
Russia/EU	1.09	1.09	1.15
India/EU	1.12	1.15	1.29
China/EU	1.27	1.44	1.53

The carbon intensity has been fairly stable in Brazil on a level more than 20 % below the EU average. The other BRICs show an upward trend, in Russia about 15 % above the World in 2010. The trend is more pronounced for India and China, about 29 respectively 53 % above EU average in 2010. This illustrates the potential for reduction in carbon intensity.

The energy mix in the energy system in a country plays an important role for the carbon intensity and this is recognised in a comparison in section 5.6 Table 5.1. Brazil had in 2010 an energy system with only 50 % fossil fuels. Russia relied on fossil fuels to 90 % but the dominant fuel was natural gas with lower carbon content than oil and coal. In both India and China coal is the dominant fuel, though India used only 70 % compared to 90 % in China. It is reasonable that carbon intensity is highest in China, lower in India and then further lower in Russia.

10.7 Potential to reduce energy intensity in the BRICs

The corresponding approach is used for energy intensity as for carbon intensity and the outcome is shown in Appendix 1 in Diagram 10.11 to 10.13. In Table 10.6 the relation between the energy intensity in the BRICs and EU is shown. A factor greater than 1 indicates that energy intensity is higher than in EU.

Table 10.6 Energy Intensity in the BRICs relative EU. Source: World Bank Open Database and own calculations

	2000	2005	2010
Brazil/EU	1.81	1.89	2.03
Russia/EU	8.12	6.62	6.47
India/EU	5.64	5.01	4.86
China/EU	6.10	6.10	5.50

The energy intensity in Brazil is close to the World average but compared to EU it is about twice as high with an upward trend indicating that Brazil has difficulties catching up with the development of energy efficiency in EU. Russia seems to have lowest energy efficiency and the highest energy intensity of the other BRICs. Compared to EU the energy intensity is more than six times higher in Russia in 2010, five and a half time in China and almost five times as high in India.

The potential for reductions is significant in all BRICs compared to EU, highest in China and lowest in Brazil. The comparison is on the macro level and does not pay any attention to different conditions in the countries like the industrial structure.

10.8 Summary and remarks

Brazil has the lowest outlet of carbon dioxide of the BRICs and their carbon intensity is lower than the world average while energy intensity is very close to the world average. Though the potential to reduce carbon and energy intensity is low the position concerning future outlet of carbon dioxide from the energy sector seems favourable. Deforestation is the big challenge for Brazil when it comes to carbon dioxide outlet.

In Russia the carbon intensity is lower than the World average, about the same as in the US and a bit higher than in EU. However, the energy intensity is the highest among the BRICs though it has declined during the first decade in the 21st century. The potential to reduce the energy intensity seems high if energy efficiency can be improved.

India shows an increasing trend in carbon intensity and the level is 12-25 % above World, US and EU averages. The energy intensity shows a downward trend but is 2.5 to 5.5 times higher than World, US and EU which indicate a substantial potential to improve energy efficiency.

In China the carbon intensity is 20-50 % higher than in World, US and EU and has been increasing over the past decade. There seems to be a certain potential for improvement of the carbon intensity. Energy intensity has declined during the past years but shows the largest potential for improvement in comparison with World, US and EU. In the next section the future will be discussed.

Section 11: Final discussion - the future for the BRICs

In section 10 the development of carbon and energy intensity up until 2010 in the BRICs has been discussed in a World, US and EU perspective with help of the Kaya identity. The future development of these parameters are crucial. All BRICs want to improve their standard of living and growth in GDP per capita is therefore essential and a faster economic growth compared to the US and EU is required.

This means that GDP per capita has to continue to increase and if the absolute level of carbon dioxide outlet should be reduced there is only three parameters left to discuss. Population, carbon intensity and energy intensity. A medium UN population scenario gives an idea of how the populations in the BRICs will develop from 2010 to 2060 in million inhabitants (UN, 2014c).

Table 11.1 UN Population scenario medium Source: UN, 2014c

	2010	2020	2040	2060
Brazil	195	211	229	228
Russia	144	140	127	115
India	1205	1353	1565	1643
China	1360	1433	1435	1313

Russia is the only country with a downward trend during the entire period and India the only country with an upward trend. Both Brazil and China seem to have a peak in their population around 2040 which might help them balance the impact of GDP growth per capita on carbon dioxide outlet. Russia has the best position and India the worst in respect of the anticipated population growth.

Brazil has the lowest carbon intensity among the BRICs in 2010 and China the highest. One important explanation is that the energy system in Brazil uses only about 50 % fossil fuels while China uses around 90 % fossil fuels. The carbon intensity in Russia and India are in between and the intensity is lower in Russia than in India. Russia uses 90 % fossil fuels but the energy mix is dominated by natural gas while India with 70 % fossil fuels are dominated by coal. The energy mix in energy systems dominated by fossil fuels and in particular coal has to change in order to lower carbon intensity. If coal can be changed to non-fossil fuels or natural gas the greatest impact can be achieved. Natural gas releases, by combustion, roughly 60 % of the carbon dioxide compared to coal. But it is not easy to change the energy mix in the short run as the use of natural gas and renewables requires new investments. The existing equipment can be seen as “sunk cost” and is charging only the operating cost. The economic competition between old equipment and new is a sort of brake in process of changing the energy mix. A further obstacle to change of energy mix is high economic growth in itself with the Chinese electricity market as an example. Though China is the largest market for wind power in the world the share of new wind power is relative modest in comparison to new coal fired plants. The annual additions of new generating capacity is so high due to the economic growth that the supply of new wind power is not sufficient.

Brazil seems to have the best position in this case and Russia the second best. Brazil has the option to use part of the ethanol produced for export in it the domestic transportation sector as infrastructure is in many areas in place. Further, the pressure for land clearances is relatively low. A substantial increase in ethanol production requires less than 2 % reduction in land use in other agricultural sectors. (Giesecke et al, 2009) China is probably in the worst situation in this respect of the energy mix and with the high economic growth rate it is difficult to switch away from a domestic fuel like coal even if the use of natural gas is increasing and China is promoting renewable energy resources like wind and solar energy.

Energy intensity is lowest in Brazil but compared to EU the double. Russia seems to have the worst position and China the second worst position. The potential to reduce energy intensity in Russia as well as China and India compared to EU is significant. But the challenge to come closer to the EU level is giant. For Brazil it takes an annual improvement of energy intensity of about 3.5 percent during 20 years and at the same time assuming that the energy intensity in EU is on the same level as 2010. Compared to the annual rates of improvement seen so far it seems less likely. For the other BRICs it seems even more unlikely.

In summary the best position is given 1 and the worst 4 in the ranking of the parameters used in the Kaya identity. Assuming that all the parameters have the same weight the total ranking is shown in Table 11.2.

Table 11.2 Ranking of BRICs Source: Own estimation

	CI	EI	POP	GDP	Total
Brazil	1	1	3	1	6
Russia	2	4	1	2	9
India	3	2	4	3	12
China	4	3	2	4	13

The simple ranking indicates that Brazil is in the best position for the future and that China is in the worst position among the BRICs closely followed by India. The BRIC countries have different positions and probably interests for the future and an interesting question is if they will continue to stick together in the climate negotiations to come.

<u>Section 12: Conclusion</u>

The first research question was how can the absolute outlet of GHGs from the BRIC countries can be expected to develop compared to the rest of the world, EU and US. The absolute outlet of carbon dioxide from the BRICs can be expected to increase faster than the world, US and EU in a business as usual scenario. A simple linear extrapolation of the current trend suggests such a development. This is also confirmed by a number of scenarios in the scientific literature. The reviewed literature suggest that if further policies and programs are introduced in the BRIC countries there is a significant potential to reduce the outlet of carbon dioxide. But many of these policies and programs may hamper the economic growth and may therefore not be implemented. The BRIC countries are most likely not willing to reduce growth as long as no dramatic climate change is observed in their countries. Therefore the conclusion is that the BRICs may continue to be a threat to the global environment.

The second research question was if any of the BRICs have a more favourable position when it comes to reducing the outlet of GHGs. It is obvious that the BRICs are different in terms of energy systems, domestic energy resources, economic structure, population and current level of income per capita. In a simple ranking of the BRICs using the parameters from the Kaya identity Brazil seems to be in the best position to deal with the future outlet of carbon dioxide, followed by Russia, India and China.

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APPENDIX 1:

Section 6:

Diagram 6.1 Annual GDP growth rate in % for Brazil. Source: World Bank Open Database

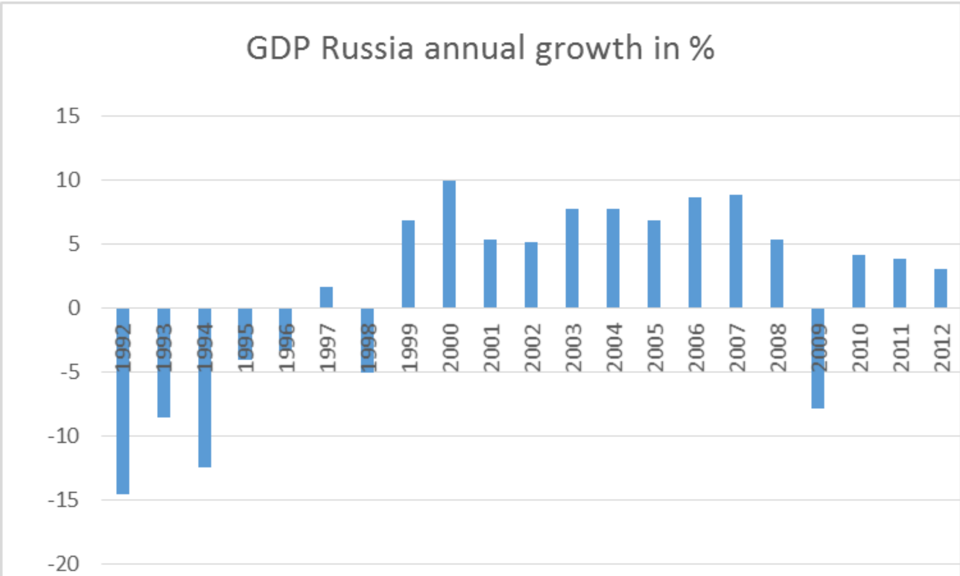

Diagram 6.2 Annual GDP growth rate in % for Russia. Source: World Bank Open Database

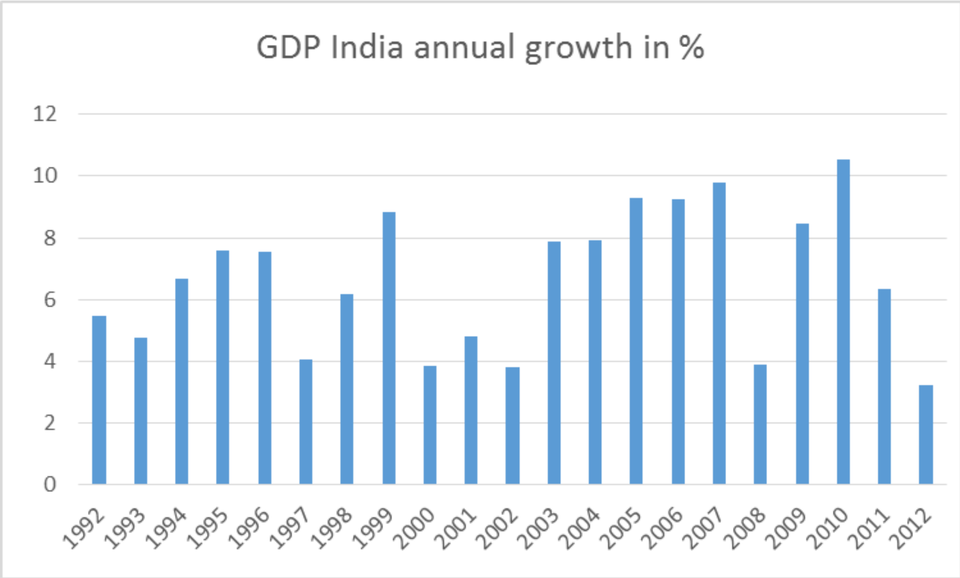

Diagram 6.3 Annual GDP growth rate in % for India. Source: World Bank Open Database

Diagram 6.4 Annual GDP growth rate in % for China. Source: World Bank Open Database

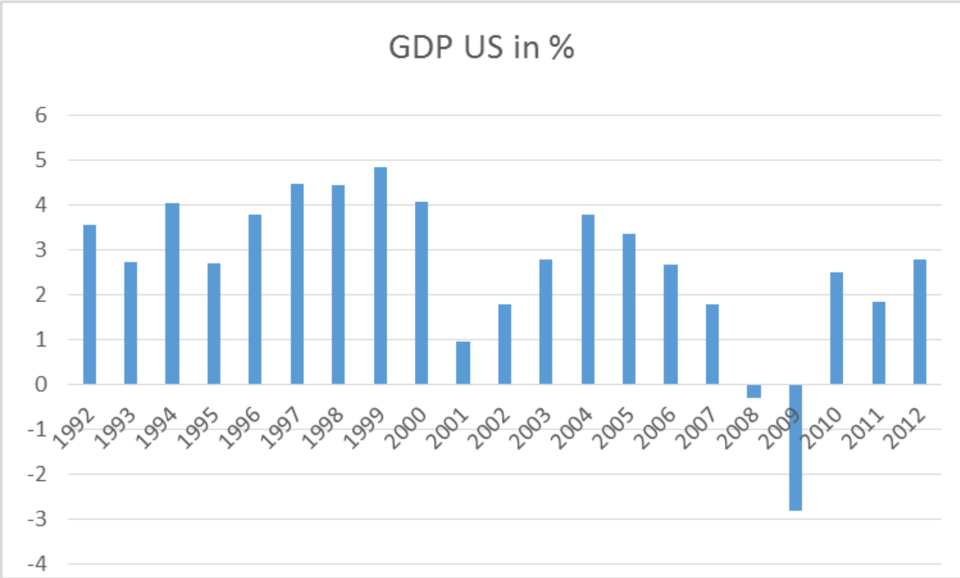

Diagram 6.5 Annual GDP growth rate in % for the US. Source: World Bank Open Database

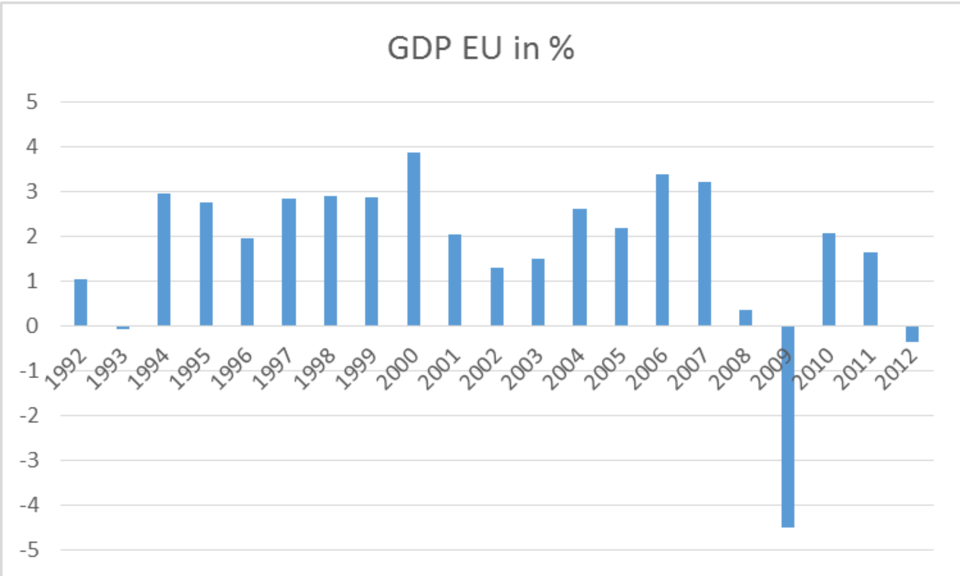

Diagram 6.6 Annual GDP growth rate in % for the EU. Source: World Bank Open Database

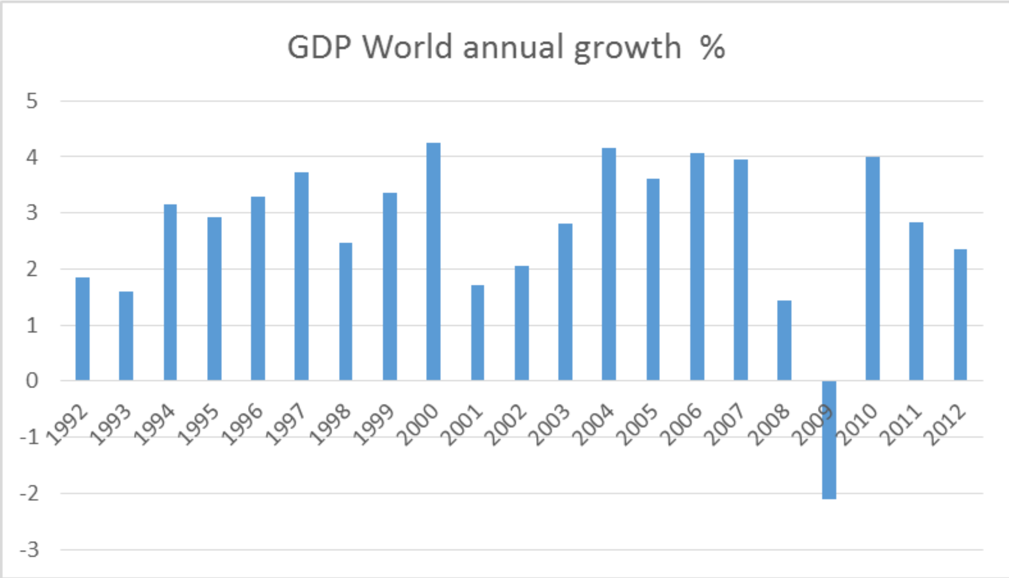

Diagram 6.7 Annual GDP growth rate in % for the World. Source: World Bank Open Database

<u>Section 7:</u>

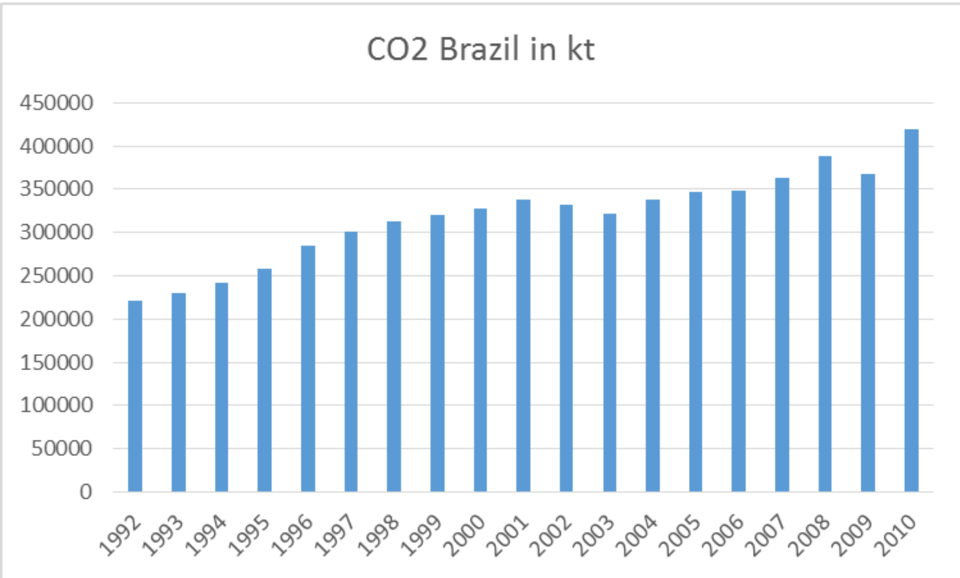

Diagram 7.1 CO2 outlet in Brazil in kt. Source: World Bank Open Database

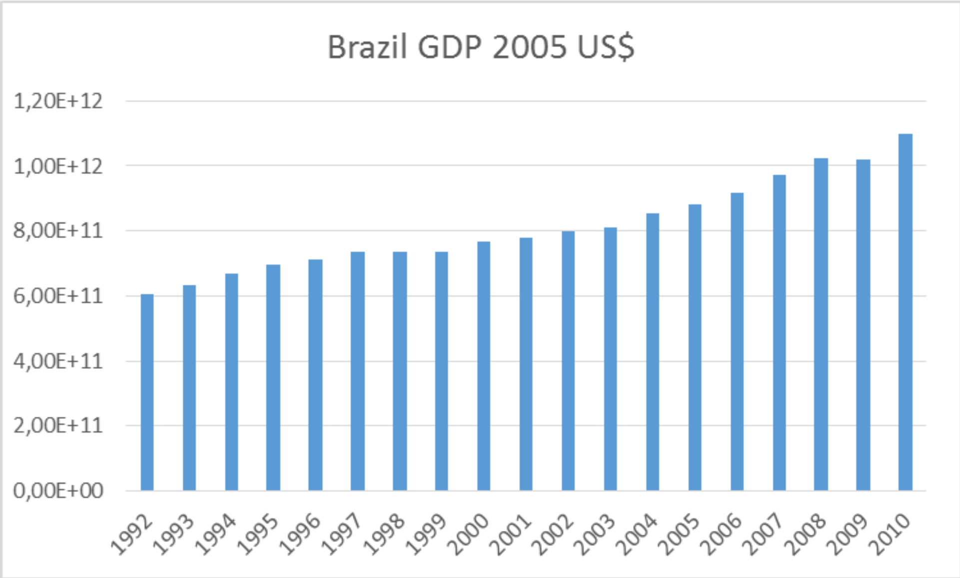

Diagram 7.2 GDP in 2005$ for Brazil. Source: World Bank Open Database

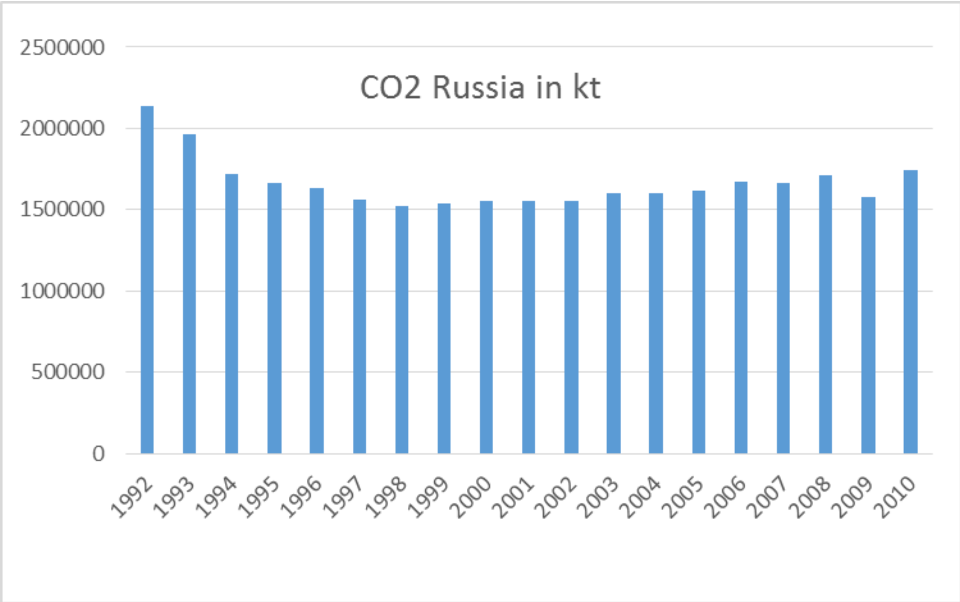

Diagram 7.3 CO2 outlet in Russia in kt. Source: World Bank Open Database

Diagram 7.4 GDP in 2005$ for Russia. Source: World Bank Open Database

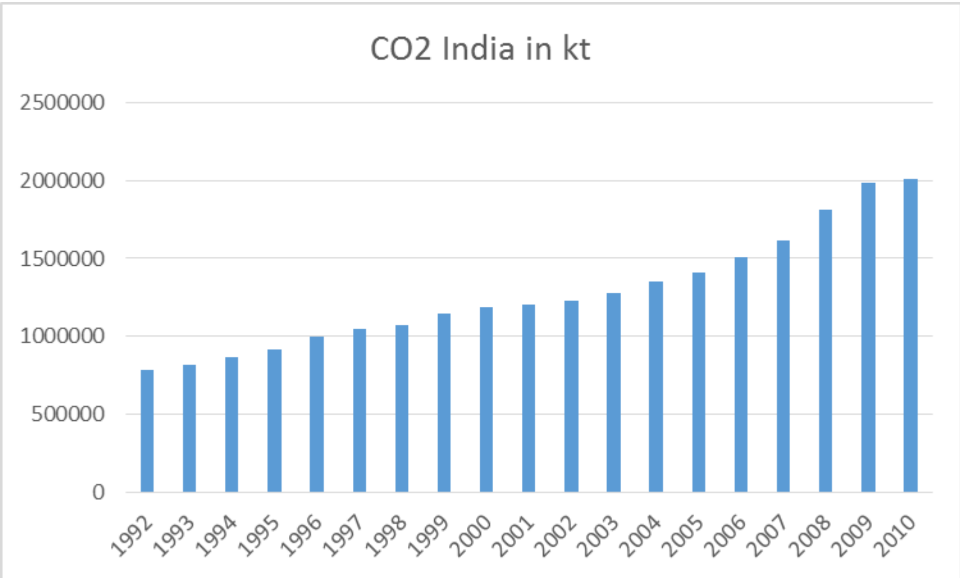

Diagram 7.5 CO2 outlet in India in kt. Source: World Bank Open Database

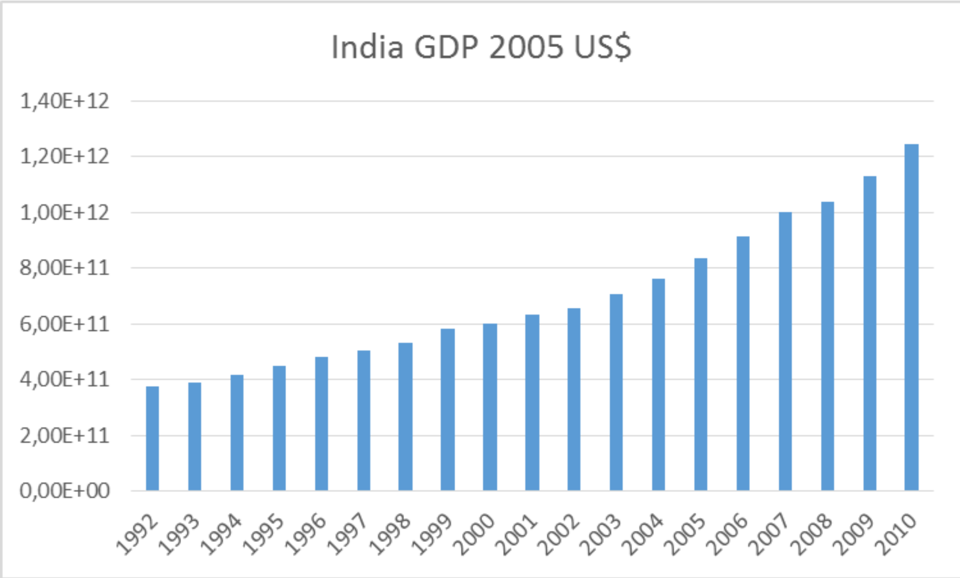

Diagram 7.6 GDP in 2005$ for India. Source: World Bank Open Database

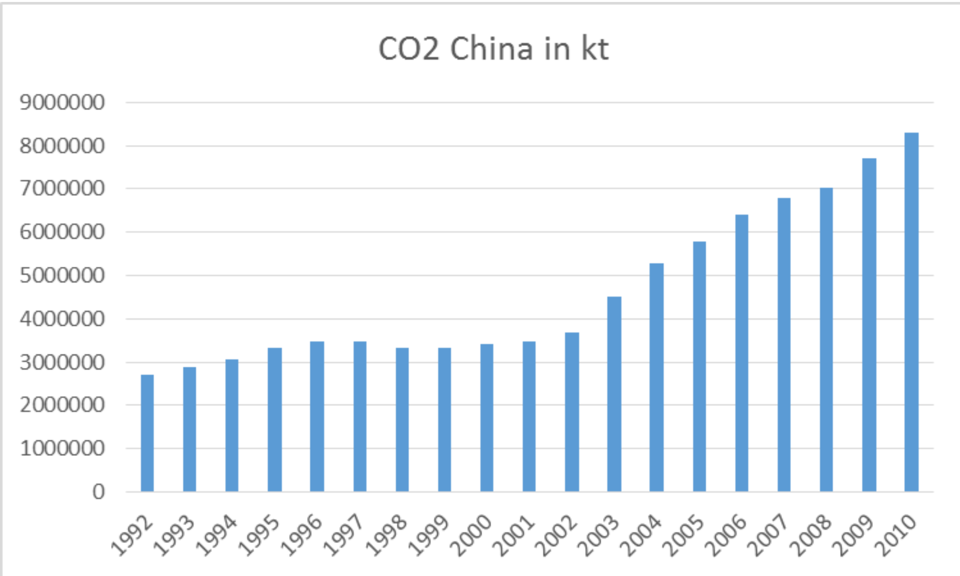

Diagram 7.7 CO2 outlet in China in kt. Source: World Bank Open Database

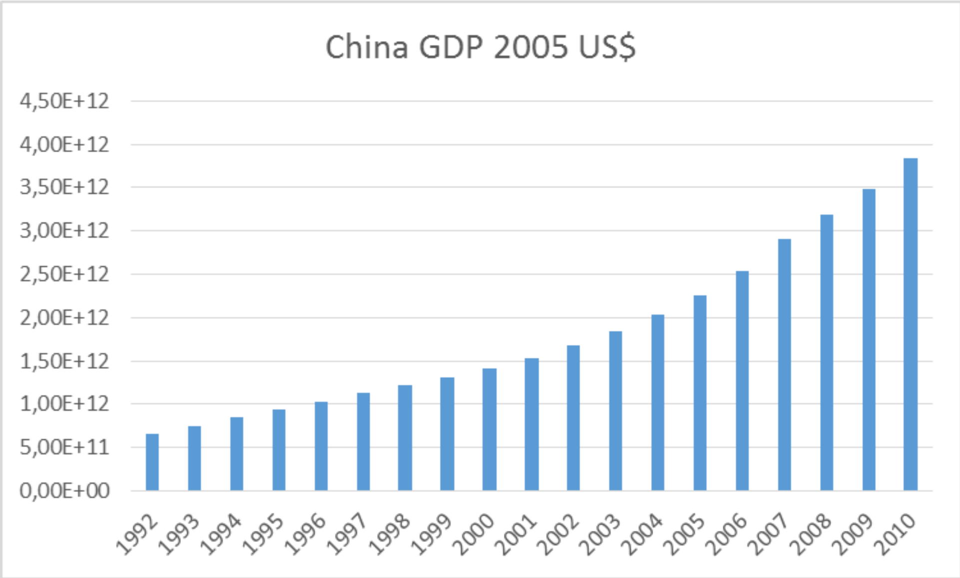

Diagram 7.8 GDP in 2005$ for China. Source: World Bank Open Database

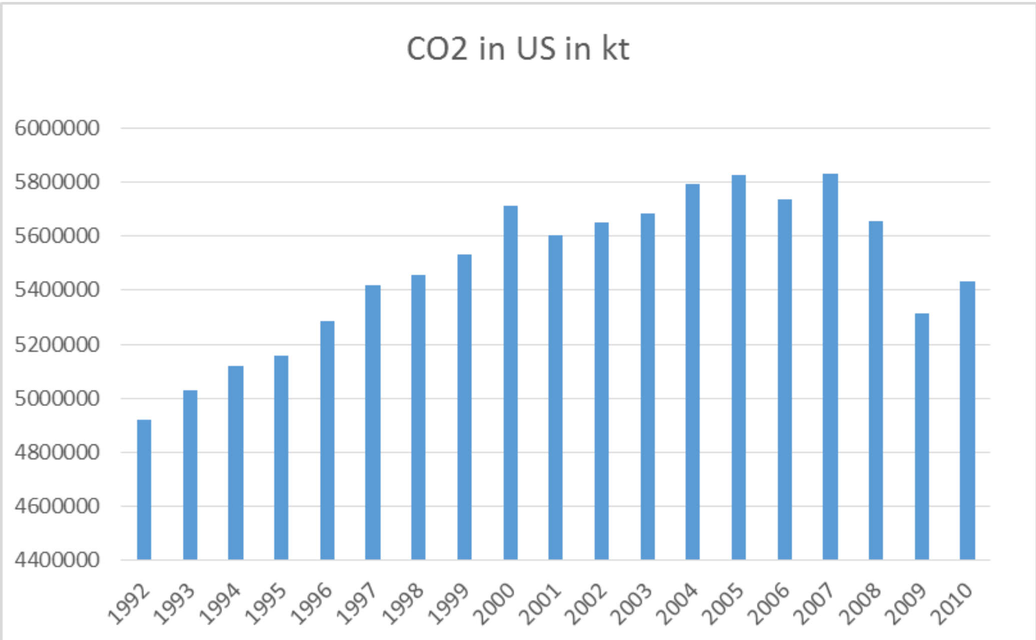

Diagram 7.9 CO2 outlet in US in kt. Source: World Bank Open Database

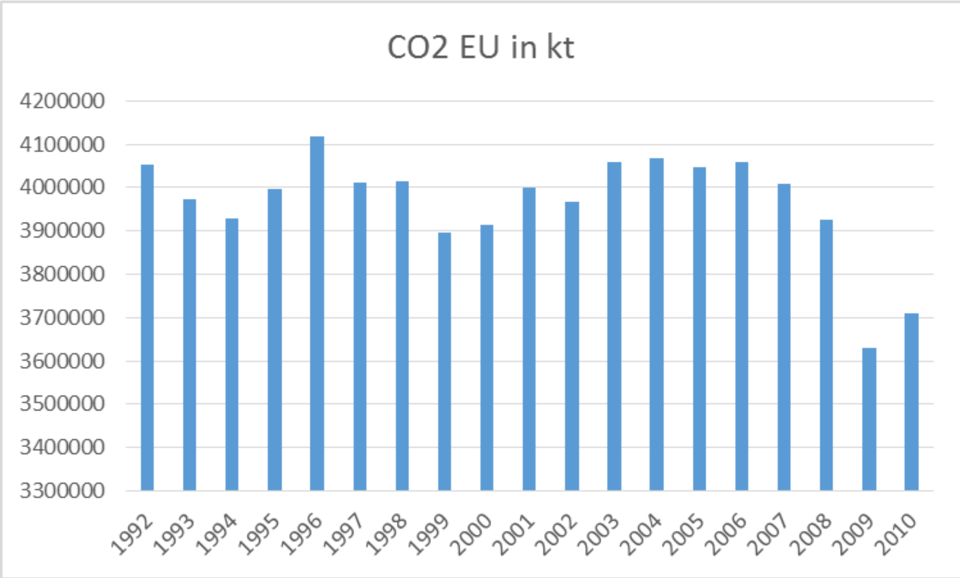

Diagram 7.10 CO2 outlet in EU in kt. Source: World Bank Open Database

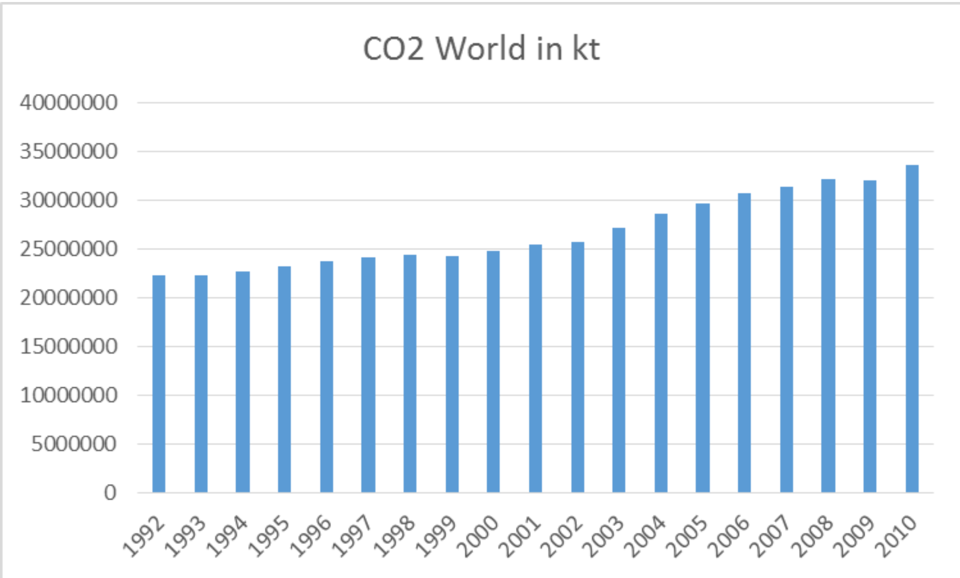

Diagram 7.11 CO2 outlet in World in kt. Source: World Bank Open Database

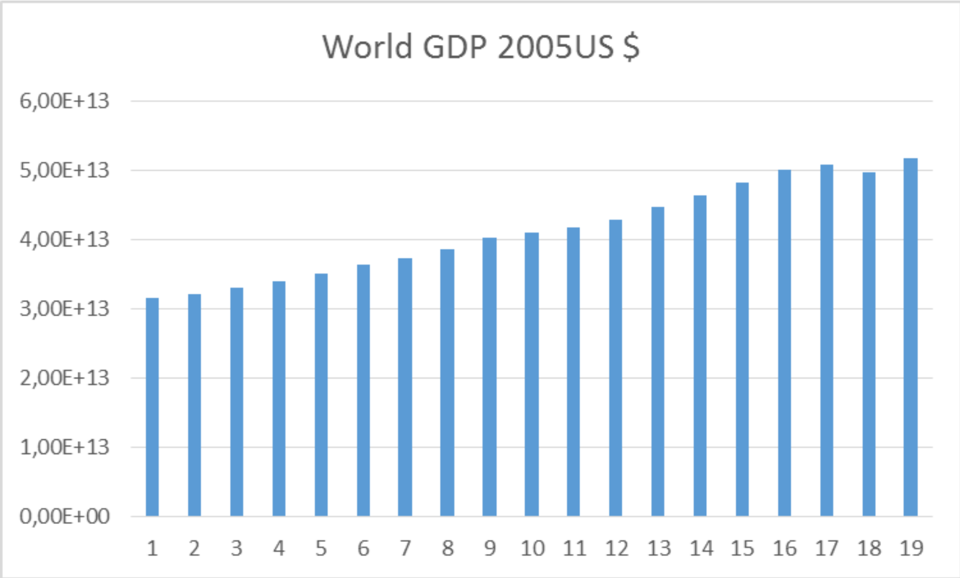

Diagram 7.12 World GDP in 2005US$. Source: World Bank Open Database

<u>Section 10:</u>

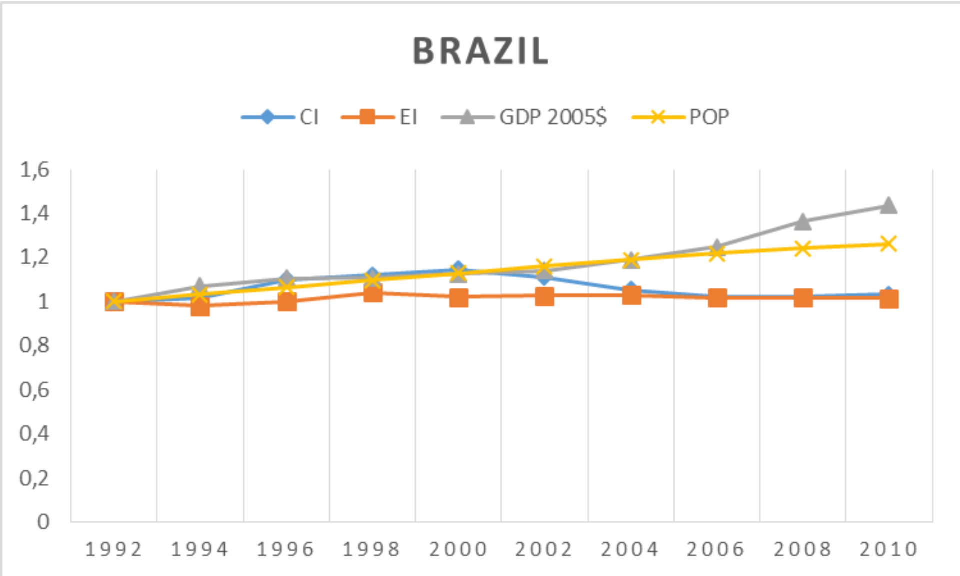

Diagram 10.1 Kaya parameters for Brazil. Source: World Bank Open Database and own calculations

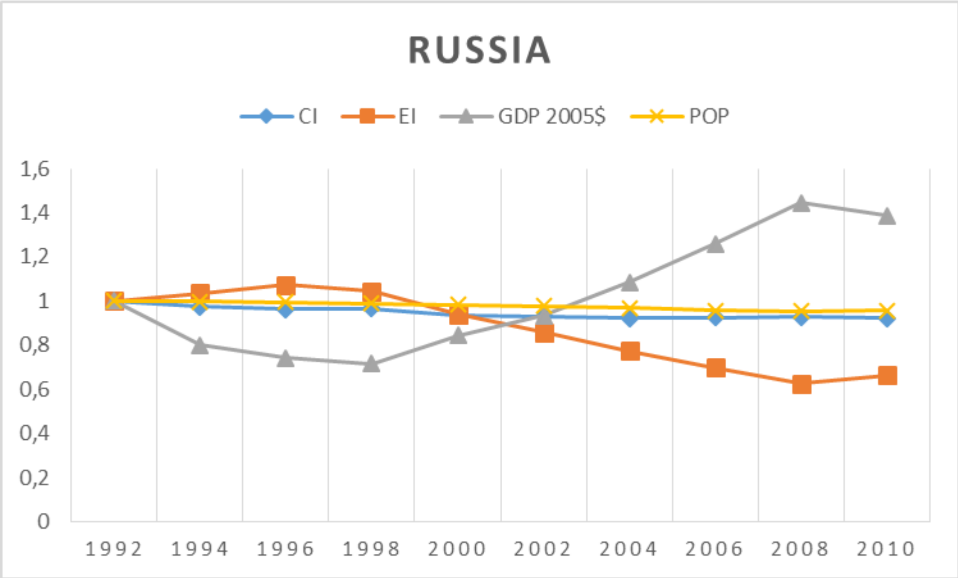

Diagram 10.2 Kaya parameters for Russia. Source: World Bank Open Database and own calculations

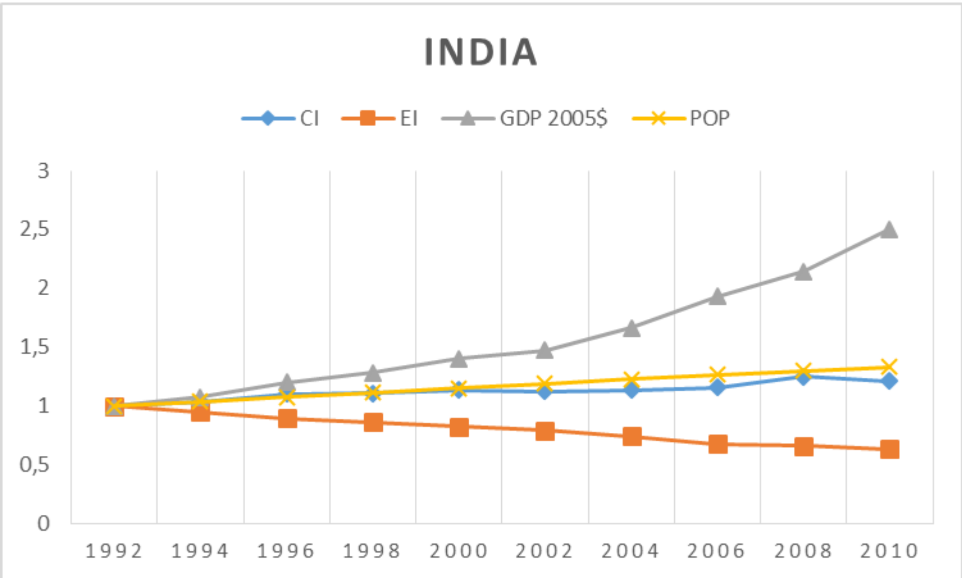

Diagram 10.3 Kaya parameters for India Source: World Bank Open Database and own calculations

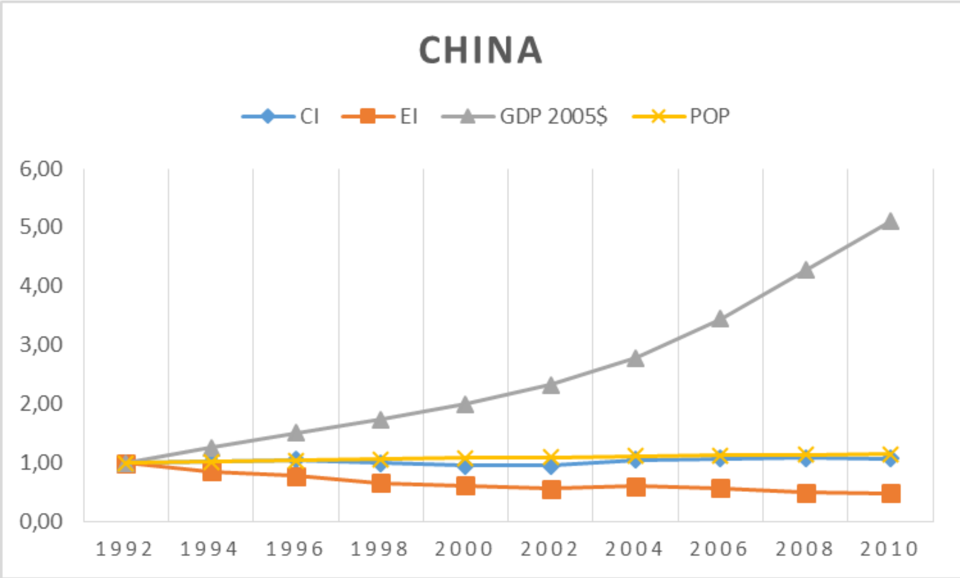

Diagram 10.4 Kaya parameters for China Source: Word Bank Open Database and own calculations

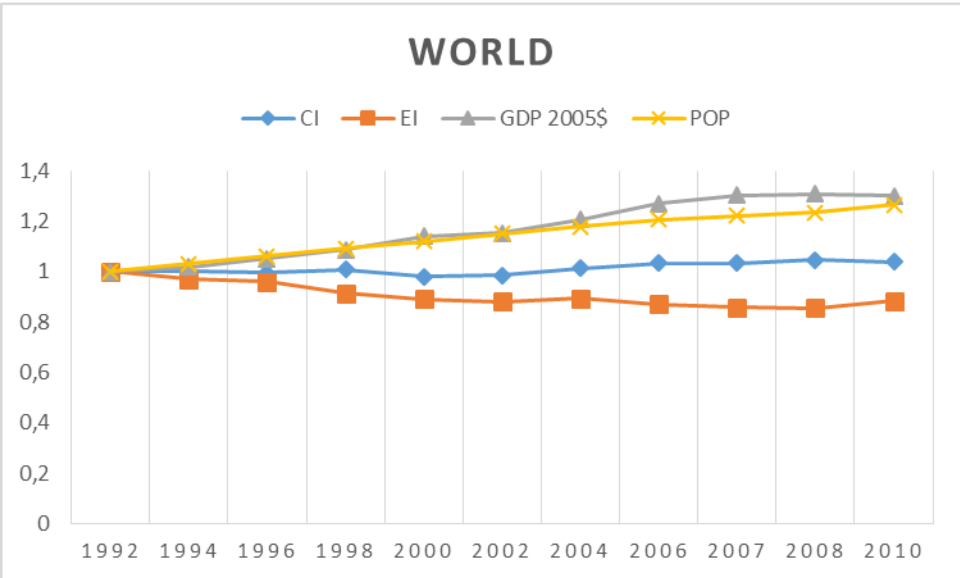

Diagram 10.5 Kaya parameters for World. Source: World Bank Open Database and own calculations

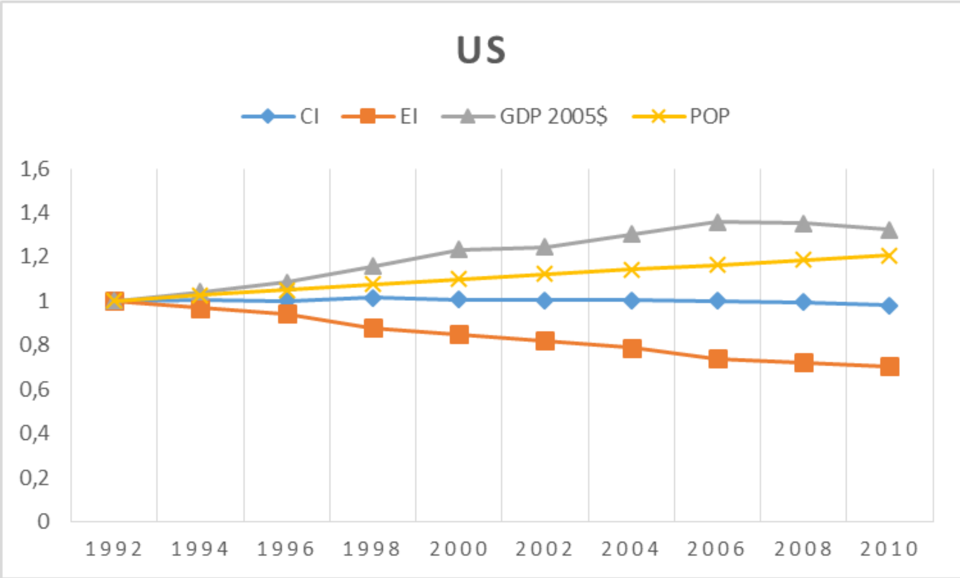

Diagram 10.6 Kaya parameters for US Source: World Bank Open Database and own calculations

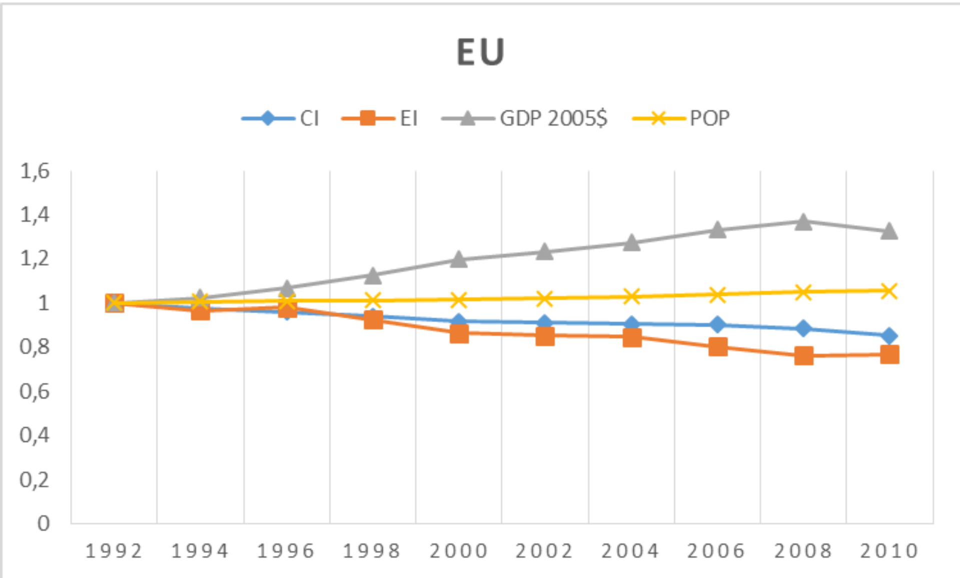

Diagram 10.7 Kaya parameters for EU. Source: World Bank Open Database and own calculations

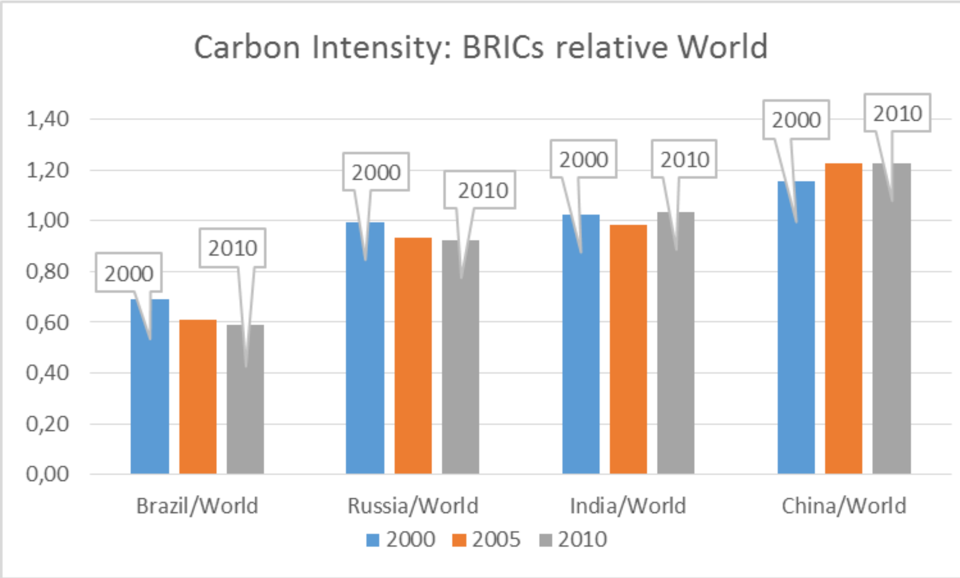

Diagram 10.8 Carbon Intensity – BRICs relative World. Source: World Bank Open Database and own calculations

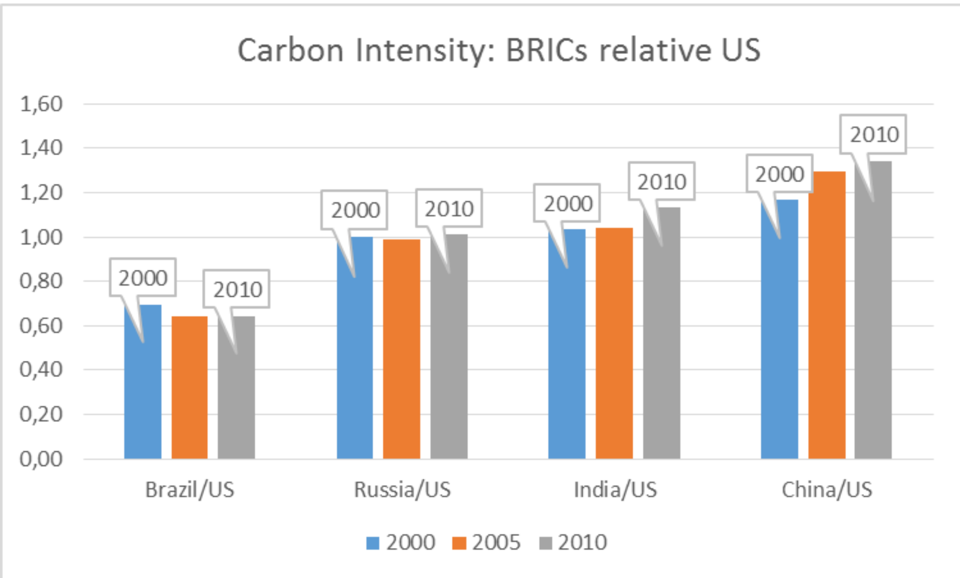

Diagram 10.9 Carbon Intensity – BRICs relative US. Source: World Bank Open Database and own calculations

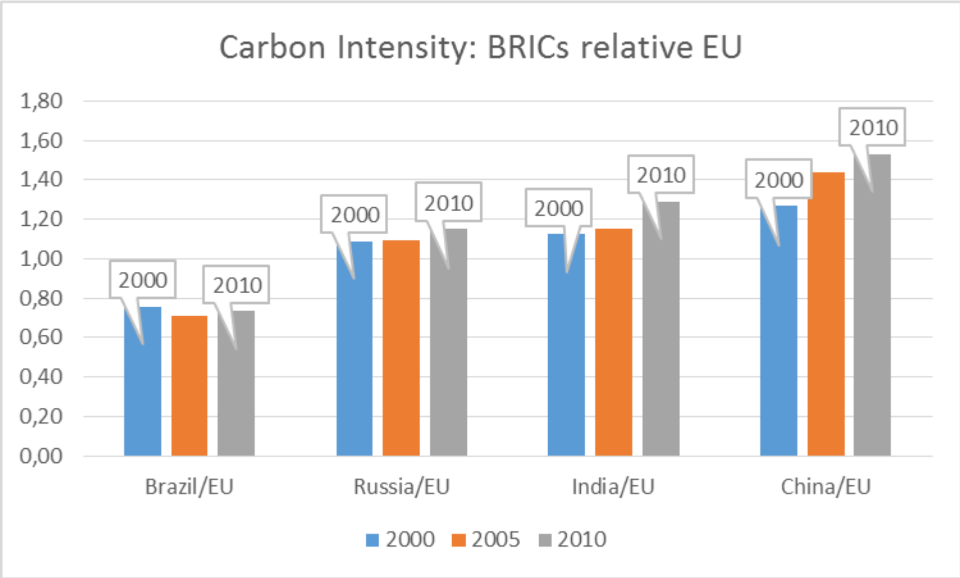

Diagram 10.10 Carbon Intensity – BRICs relative EU. Source: World Bank Open Database and own calculations

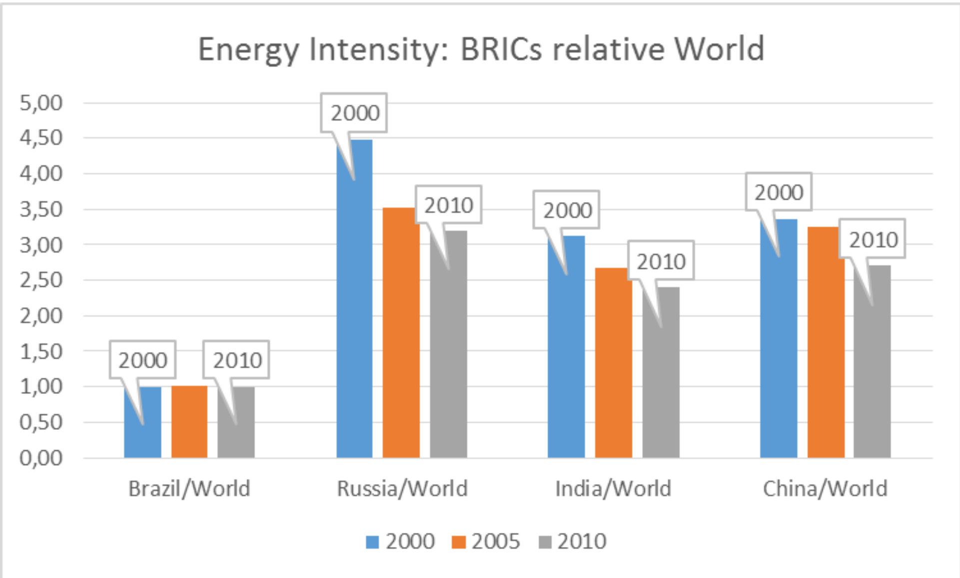

Diagram 10.11 Energy Intensity – BRICs relative World. Source: World Bank Open Database and own calculations

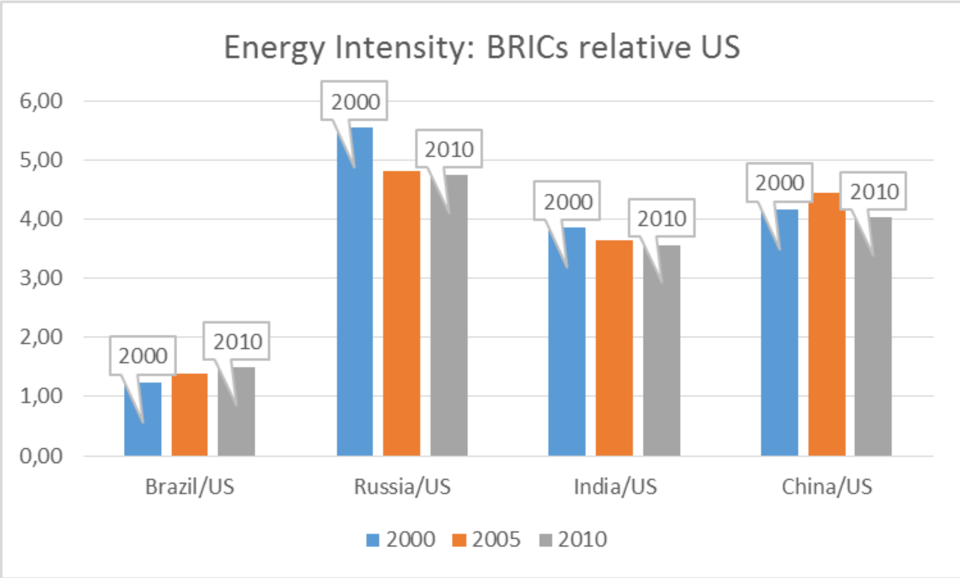

Diagram 10.12 Energy Intensity – BRICs relative US. Source: World Bank Open Database and own calculations

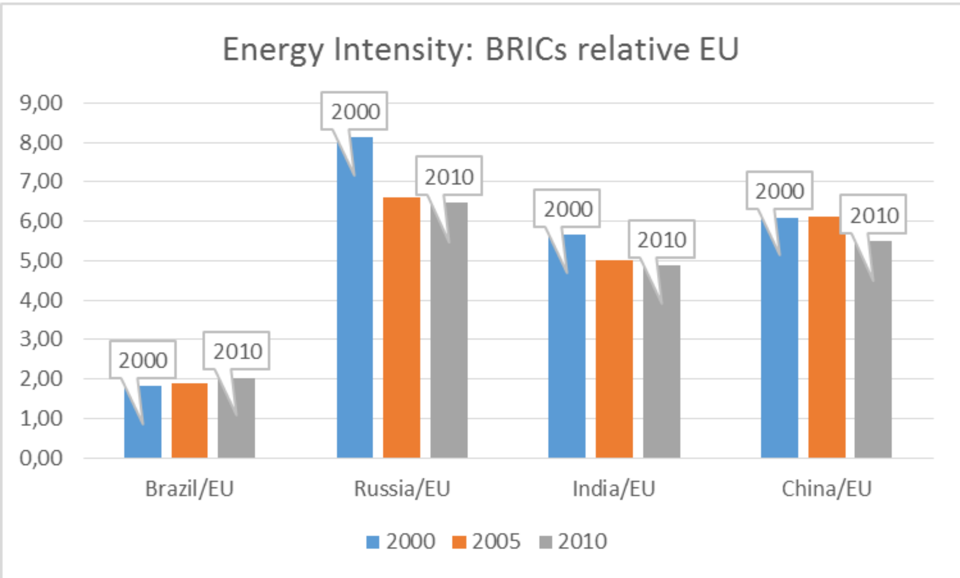

Diagram 10.13 Energy Intensity – BRICs relative EU. Source: World Bank Open Database and own calculations